# THE EPIDEMIOLOGY OF DENTAL CARIES IN EDINBURGH CHILDREN : A STATISTICAL EVALUATION

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# INTRODUCTION

The literature relating to the epidemiology of dental caries incidence in this country is meagre. There are several possible reasons for this. The complexity and multiplicity of clinical problems have tended to result in the concentration of research endeavour in these fields. Also, research of this nature is usually short term, therefore more productive of quick results. In contrast, epidemiological studies are time-consuming and long-term in their execution. The lack of epidemiological data in Britain is to be regretted because, in the field of medicine in general the epidemiological approach has been found valuable and in the study of dental caries the epidemiological method, revealing as it does group characteristics peculiar to the disease, provides additional evidence necessary for an understanding of the influences of the various environmental factors on its incidence.

The aetiology of dental caries is still imperfectly understood, but from existing knowledge it is clear that there exists independently predisposing and provoking factors in the causation of this disease. One of the more important of the predisposing factors has its origin in those conditions which influence tooth structure and emphasises therefore developmental and nutritional factors. The work of Mellanby, for example, has demonstrated a direct relationship between specific dietary intake and dental caries incidence.

On the other hand, the provoking factors appear to exert their influence upon the intimate oral environment of the tooth itself and are related to the purely local non-nutritional effect of diet, together with the influence of certain acidogenic micro-organisms found in the mouth. The nature and character of these provoking factors were amply demonstrated by the work of Miller at the end of the 19th century, when he formulated the chemico-parasitic theory of dental caries, a theory which has been further amplified and confirmed by subsequent investigation.

Miller's work implied an association of dental caries with oral hygiene, an association which is more fully demonstrated later in this thesis. The work of Mellanby, on the other hand, showed that there was a direct relationship between specific dietary intake and dental caries incidence. It may be said, then, that both schools of thought, though apparently divergent in view, do in fact demonstrate in effect the association between personal behaviour, i.e., oral hygiene and food habits and the incidence of dental caries. Both of these are, of course, intimately related to standards and conditions of living in different social groups.

However, the precise relationship of oral hygiene, food habits and other social factors with dental caries will vary from time to time and from one social group to another.

This changing association is best regarded as due to the interaction of oral hygiene, food habits and tooth structure on the one hand, and the intimate tooth environment on the other. To take an extreme example, poverty is likely to be associated with both defective tooth structure and caries-producing oral environment. A relatively high standard of living, however, is perhaps more likely to demonstrate the association between caries-producing oral environment and caries incidence and show no association with tooth structure.

For example, in the investigation of Miller and Crombie in 1939 in a poor district on Tyneside, the relationship between standards of personal hygiene and poverty and food intake were obviously much closer than they are to-day, with the generally higher standards of living throughout equivalent sections of the population.

In this thesis the prevalence and aetiology of dental caries among school children in Edinburgh in relation to this basic distinction between tooth structure and tooth environment are investigated by examining variations of caries incidence for different biological and social groups, in particular contrasting fee-paying and non-fee-paying school children and twins in addition to the usual factors of age and sex.

The absence of any published, comprehensive, epidemiological data relating to the incidence of dental disease in Scottish children provided the reason for this investigation. It was the writer's privilege to teach and to investigate the subject of prevention of dental disease and so it seemed a necessary prerequisite to obtain at first hand a wide knowledge of the dental state of the population of Edinburgh, who must invariably provide most of the material for teaching and investigation. Logically, from the very nature of dental caries, prevention must start with the child and for this reason, then, this study is confined to school children.

It was appreciated that considerable information of this nature might be obtained from the School Medical Service and other public sources, but it was thought that data obtained in this way would inevitably have serious limitations for many reasons.

Firstly, such data have been obtained by a large number of different examiners, each one of whom may differ in his standard of examination and assessment of dental disease.

Secondly, such data have been obtained for the purpose of treatment and the emphasis is inevitably placed upon treatment needs, which are not necessarily identical with the requirements of an investigation of this nature.

Thirdly, much of the data obtainable from clinics can hardly be regarded as representative of the population since to a considerable extent the children who actually attend for treatment can be considered as self-selected.

For these reasons, then, it was decided that, to provide basic data relating to dental disease which would be reasonably consistent throughout, fresh data would have to be obtained, and that preferably only one examiner should be concerned in its collection.

The objectives of this study were therefore:-

(a) to obtain information relating to the incidence of dental caries in school children and, from this knowledge, to derive norms which could be used in future investigations to compare other samples of the same or different populations.

(b) Similarly, to obtain data regarding the time of eruption of the permanent teeth.

(c) To examine the possibility that constitutional factors as distinct from environmental factors may play some part in the incidence of dental caries and, if so, to attempt to obtain some measure of their importance.

(d) To determine whether an association existed between the incidence of dental caries and socio-economic factors.

(e) to examine the possible relationships that may exist between physique, in terms of height, weight and stage of maturity, and dental caries incidence.

(f) Finally, from such cross-sectional data to obtain information to show what further investigations of dental caries in Edinburgh children might most profitably be undertaken.

# CHAPTER I

## Methods of Investigation

The data to be described were obtained in the main from two samples.

The first sample consisted of all the available population of three schools, a total of 2,251 children. These schools were selected to provide a good cross-section of Social Classes III, IV and V, as defined by the Registrar-General. School A was attached to a training college for teachers. Since applications by parents to have their children admitted to this school exceed the available vacancies, a considerable measure of selection is adopted by the school in the enrolment of pupils.

These children can therefore be regarded as the more intelligent of this first sample. It is assumed also that they come from families whose standards of child care and general management of the home are high. This assumption seems justified by the fact that the parents have had to take the initiative in applying to have their child admitted to this school, rather than adopt the passive course of permitting the local authority to direct the child to the appropriate local authority school. In consequence, the majority of these children are drawn from a wide selection of areas of the city and little or no regional bias is found among them. They are therefore regarded as a good cross-section of Edinburgh school children of this particular social class.

On the basis of the occupation of the parent or guardian as recorded by the school, these children are mostly representative of Social Class III.

The second school (School B) is a local authority one in a slum area of the city and the children are mostly representative of social classes IV and V.

The third school (School C) is also a local authority school, situated in a rehousing area, and most of the children represent social classes IV and V.

In both Schools B and C the children reside within a well defined area near the schools.

The second sample was obtained for the purpose of a joint investigation with H. S. Provis and R. W. B. Ellis of the Department of Child Life and Health, University of Edinburgh, who were making an anthropometric study of Edinburgh school children. Since socio-economic factors often influence growth, and also for the purpose of this present study, it was decided that a proportion of the children studied should derive from private, fee-paying schools.

From data kindly provided by the Deputy Director of Education for the City of Edinburgh the proportions were obtained of children at each year of age in the total child population of Edinburgh attending private and local authority schools respectively during 1951.

With the statistical assistance of Dr. L. Stein of the Department of Public Health and Social Medicine, a stratified sample was selected from previously chosen schools. The proportion of non-fee-paying to fee-paying children in the sample was maintained in the same proportions as was known to occur in the population under study.

Nine schools were chosen from which the sample was selected. Ideally, the sample would have been taken from a greater number of schools, but for practical considerations in order to economise time and labour and to avoid too great a disruption of the school organisation, it was decided to choose a smaller number of schools, but with large enough numbers of children to permit selection of the sample size required.

Of the nine schools chosen, five were local authority and four were fee-paying. In the local authority schools the children were randomly selected in one year age groups, and in the 5 - 14 year old age group the sample is entirely random. In one of the secondary schools, however, the small numbers available in the 16 - 17 year old groups made random sampling impossible and most of the children available had to be chosen.

In the fee-paying schools the smaller numbers required made sampling by random numbers unnecessary and selection was made by taking every third child in the 5 - 14 year old age group. With the older children, the limited numbers available made true random selection difficult and, at times, most of those available had to be chosen.

Most of the dental examination of these two samples of children were made between the Spring Term of 1951 and the Spring Term of 1952, but due to difficulty in obtaining adequate samples of the older age groups, this work was not completed until 1953. The total number of children examined was 1,730.

Later the opportunity occurred of examining 53 girls in the age range 12 to 17 at another fee-paying school, and these are included with the previous samples.

Finally, 224 pairs of like-sex twins were examined between October 1953 and July 1954.

With the co-operation of the Chief Executive School Medical Officer and the Chief Dental Officer, the head teachers of all schools under the Local Authority were asked to return a list of all twins on their school register. From these returns a list of all twins was made, their dates of birth and school recorded and arrangements were made to visit each school and examine those twins selected for the study.

Like-sex twins only were selected. The reason for this was to avoid the complications which would be introduced into the subsequent analysis by the observed difference which exists between the sexes in respect of their dental caries experience. The sex difference is a measurable one. In this way it was hoped that the differences between monozygous twins and those between dizygous twins could more accurately be assessed. No other method of selection was adopted and schools were visited in order of convenience by prior arrangement with the head teachers.

The total examined, i.e., 224 pairs, represents almost 48 per cent of the theoretical number of like-sex twins in Education Authority schools in Edinburgh. The total number returned by the various head teachers was 232 like-sex pairs so that in fact over 96 per cent of those made available were examined.

Methods of Examination

The children were examined in the schools during school hours. The standards of accommodation provided varied considerably from school to school and therefore, to obtain illumination as standardised as possible, an Angle-poise lamp using a 60 watt bulb was carried as routine equipment. All dental examinations were carried out using this illumination regardless of the standard of natural lighting available. A portable head rest, designed to attach to the back of an ordinary domestic chair was used to provide stability for the child's head during examination, which was made using a plane mirror and Sharp Ash No. 54 probes. The dental findings were dictated to an assistant, who recorded them on a standard dental chart.

Permanent Teeth

Dental caries and all fillings were recorded for each tooth and for each surface of the tooth involved. All missing teeth were recorded and, whenever possible, the child was asked the reason for such loss. This was necessary for some of the older children when it was suspected that certain teeth had been extracted for orthodontic purposes or lost because of accidents. Whenever such a diagnosis was made the fact was recorded and in the subsequent analysis such teeth were disregarded since no assumption could be made as to their dental caries experience.

Deciduous Teeth

All deciduous teeth were likewise recorded, but no attempt was made to verify possible cause of tooth loss since it was considered that no reliable information could be expected from children in the age groups concerned.

Oral Hygiene

For every child examined in this study with few exceptions the child's standard of oral cleanliness was assessed as good, fair or neglected, and formed in effect a continuous scale.

Truly objective criteria of oral hygiene are difficult to define and in consequence the findings must inevitably be subjective to some extent.

Oral hygiene was assessed as follows:-

Good : When the teeth were found to be clean and free from staining, especially on the accessible surfaces.

Neglected: When the presence was noted of materia alba, of food debris, not of recent or immediate origin and/or staining of accessible tooth surfaces.

Fair: When the observed condition of the teeth was regarded as intermediate between the two extremes.

Eruption of Permanent Teeth

All teeth unerupted were recorded as such. Teeth emerging were recorded by the distance emerged, measured in millimetres. Up to 2 millimetres a tooth was regarded as just emerging and recorded as such.

Birth Rank

This was recorded for each child and was obtained from older children by direct question as to the number of older or younger siblings. For the younger children, class teachers obtained this information.

Age

The age of each child was calculated from date of birth to exact date of examination and expressed to the nearest 1/100th of a year.

The Measurement of Dental Caries

The unit of measurement chosen is one carious tooth. The dental caries experience of an individual is thus expressed in the sum of all decayed, missing and filled permanent teeth observed (D.M.F.). This is the basis of the D.M.F. index, first used by Munblatt (1933) and more widely introduced by Klein, Palmer and Knutson (1938). In this way, past experience of the disease, in terms of treatment, i.e., extractions and fillings, is included with present untreated carious teeth, giving a picture of the total dental caries experience of the individual at the time of examination.

The use of this index, however, involves the assumption that teeth recorded as missing were lost as the result of dental caries. Since teeth are sometimes lost for other reasons, some error may thus be introduced. In children, loss of permanent teeth for reasons other than dental caries is confined to those teeth extracted for orthodontic reasons and those lost or extracted because of accidents. Error due to this cause can be reduced by obtaining a dental history from the child and this was done whenever possible in this study.

The remaining sources of error are due to recording as missing those teeth which are congenitally absent, or those whose eruption has been seriously delayed far beyond the usual age.

Jackson (1950) reported that in a survey of 1000 school children of mixed ages, accidental loss accounted for four incisor teeth; orthodontic loss, as far as could be determined, accounted for 16 first permanent molars and 6 premolars. He emphasised that the probability that the first permanent molars were also carious is high and therefore their inclusion among the other decayed, missing or filled teeth would entail only a very small error.

Congenitally missing teeth are rare and their inclusion in the total dental caries score would produce a negligible error.

Deciduous Teeth

The measurement of dental caries in the deciduous dentition presents certain difficulties and the assessment of dental caries experience by summation of all decayed, missing and filled teeth is only possible up to the age of five. At five years of age the deciduous incisors begin to be exfoliated as a normal physiological process, and therefore no assumption can be made regarding their carious experience.

Jackson (1950) suggested a modified D.M.F. index for use with the deciduous dentition. He used the initials d.m.f. (in lower case figures) to represent decayed, missing and filled deciduous teeth. This index can be used up to and including five years of age on the assumption that all teeth found to be missing were extracted because of dental caries. However, from five years up to 8.99 years the d.m.f. excludes from consideration all incisor and canine teeth and applies only to the deciduous molars.

In this study, the d.m.f. score was calculated for the age range 5 - 8 years inclusive, but included the deciduous canine teeth since examination of the data did not suggest that the deciduous canine teeth were prematurely exfoliated in a sound condition.

Stones, Lawton, Bransby and Hartley (1951), reporting the time of shedding of deciduous teeth, gave the average time of shedding the deciduous canine as follows:-

Boys - Maxillary (excluding extractions) 11.60 ± 0.14

- Mandibular (excluding extractions) 10.73 ± 0.13

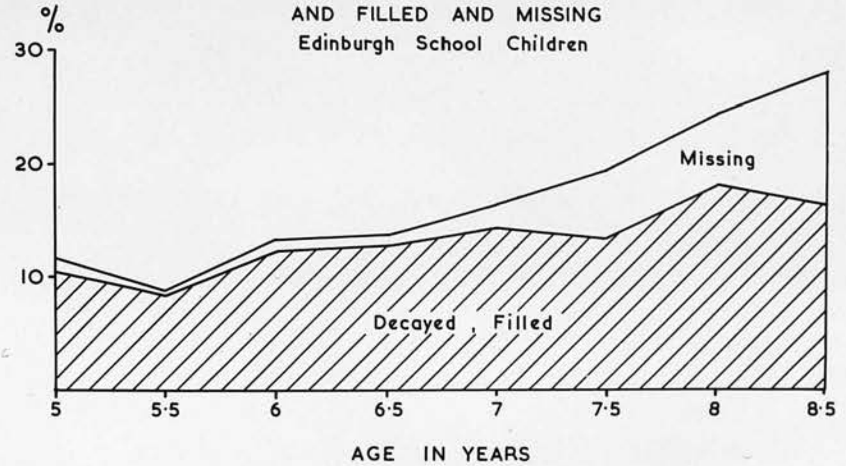
Girls - Maxillary (excluding extractions) 10.75 ± 0.21

- Mandibular (excluding extractions) 9.83 ± 0.22

These data would appear to confirm that any error introduced by including deciduous canine teeth would be small.

Figure 1 presents graphically the percentage of deciduous canine teeth, decayed or filled and missing in 1,346 Edinburgh school children aged 5.00 to 8.99 years. See also Table I in the Appendix.

FIGURE I
PERCENTAGE OF DECIDUOUS CANINE TEETH DECAYED AND FILLED AND MISSING
Edinburgh School Children



The discrepancy which exists between chronological and developmental age in individual children renders comparison between groups of children difficult at times because of the possible differences that may exist between them in numbers of teeth erupted. In order, therefore, to reduce such possible differences in future comparisons, children were grouped according to the number of teeth that they had erupted. (Extracted teeth were counted as having erupted.) Since the sequence of eruption of the various morphological classes of teeth is reasonably consistent throughout the population, it was decided to group the children in the following way.

The groups were defined by units of four teeth erupted and children allocated to the appropriate group, thus:

| | | |
|---|---|---|
| Group O | No permanent teeth erupted | |
| Group I | 1 - 4 | permanent teeth erupted |
| Group II | 5 - 8 | " " " |
| Group III | 9 - 12 | " " " |
| Group IV | 13 - 16 | " " " |
| Group V | 17 - 20 | " " " |
| Group VI | 21 - 24 | " " " |
| Group VII | 25 - 28 | " " " |
| Group VIII | 29 - 32 | " " " |

Grouping children in this way would seem to achieve a closer approximation to developmental age rather than to chronological age.

Groups of four teeth erupted were chosen since (disregarding differences between mandibular and maxillary teeth) the equivalent tooth in each quadrant emerges into the mouth fairly closely in time with those of the other quadrants, and logically that would seem to be the best method of grouping.

The greatest difference lies between mandibular and maxillary teeth, but the mean difference is, with one exception, under one year for the data on Edinburgh children. The greatest difference is in respect of the upper and lower canine teeth in girls, which is 1.10 years. In boys the greatest mean difference is for the lateral incisors and equals .88 years.

The smallest difference is between upper and lower first permanent molars with a mean difference of .06 years for girls and .08 years for boys. The values for the sexes combined is given in Table 1.

Table 1

Mean Ages of Eruption of Maxillary and Mandibular Permanent Teeth for Males and Females combined and the Differences in Means of Upper and Lower Corresponding Teeth

| Tooth | Mean Age of Eruption MANDIBLE | Mean Age of Eruption MAXILLA | Difference in Mean Age between Mandible and Maxilla |
|---|---|---|---|
| 1st Incisor | 6.94 | 7.71 | - 0.77 years |
| 2nd Incisor | 7.68 | 8.49 | - 0.81 " |
| Canine | 10.65 | 11.50 | - 0.85 " |
| 1st Premolar | 10.95 | 10.56 | + 0.39 " |
| 2nd Premolar | 11.52 | 10.96 | + 0.56 " |
| 1st Molar | 6.37 | 6.33 | + 0.04 " |
| 2nd Molar | 12.09 | 12.20 | - 0.11 " |

The data presented are derived from the examination of 1,972 boys and 2,062 girls who ranged in age from 5 to 17 years. The distribution of these children by age and sex is shown in

Figure 2 below. and Table II in the Appendix.

FIGURE 2

DISTRIBUTION BY AGE AND SEX OF 4.034 EDINBURGH CHILDREN

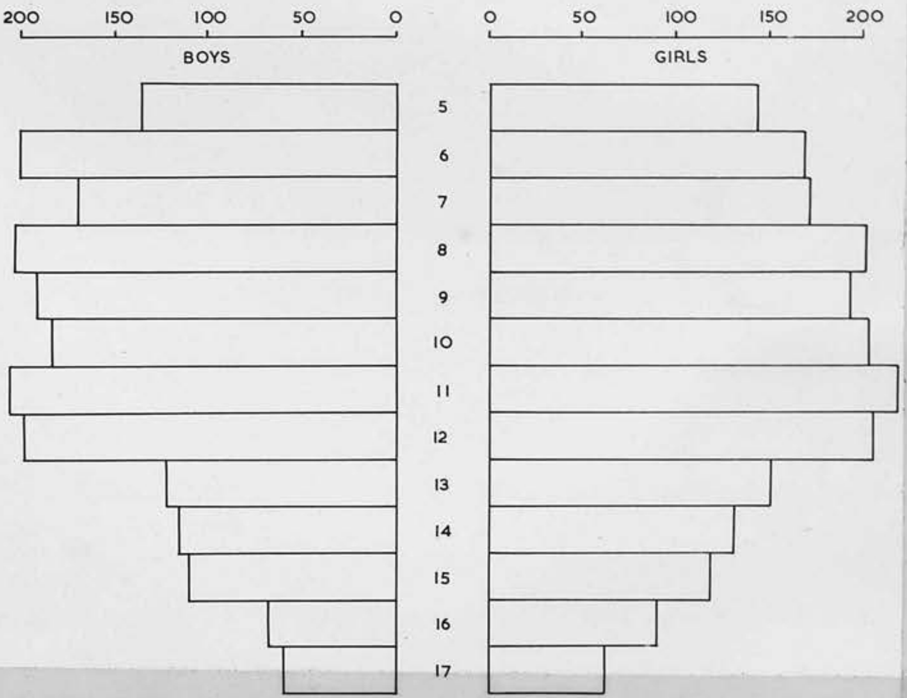
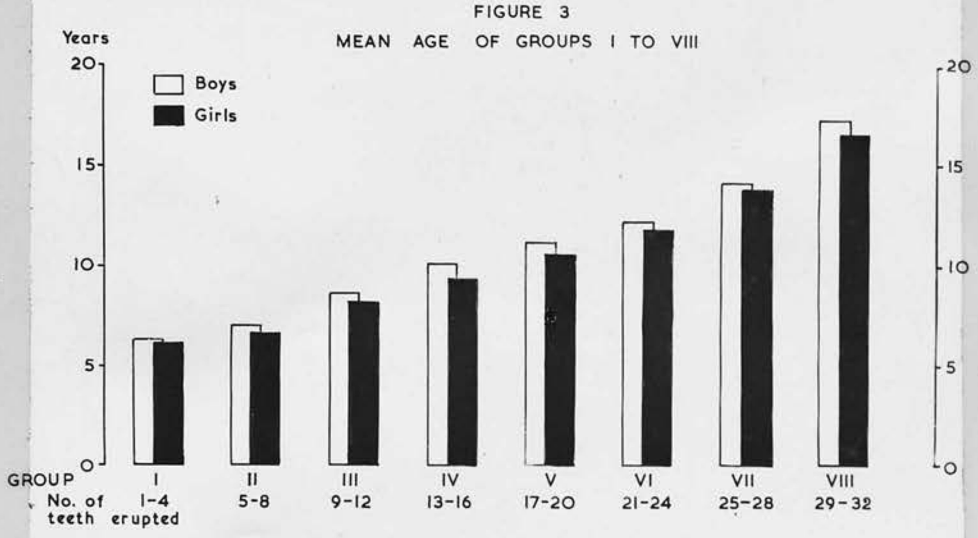



Figure 3 below shows the mean age of boys and girls in each of the Groups I to VIII. The data are also presented in Table III in the Appendix.

FIGURE 3

MEAN AGE OF GROUPS I TO VIII



# CHAPTER II

## The Incidence of Dental Caries

As previously stated, one of the purposes of this investigation was to obtain information regarding the prevalence of dental caries in school children in order that some "yardstick" might be obtained against which could be measured other samples of children either from the same or different populations. Furthermore, this information would provide a basis for comparison with future data and thereby enable possible variations in dental caries experience to be recognised.

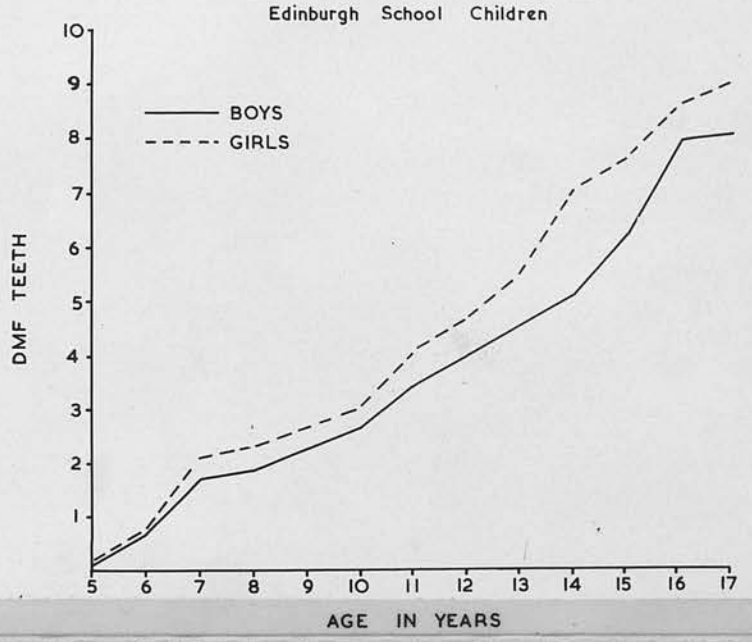
Since the end of the Second World War comparatively few studies of dental caries incidence have been made in Britain. Coumoulos and Mellanby (1947) made a study of the dental conditions of five-year old children in London and comparison was made between children living in institutions, children attending private schools and children attending L.C.C. schools. Weaver (1950) investigated and compared the dental state of 5 and 12 year old children in North and South Shields and West Hartlepool. Mellanby and Mellanby (1948, 1951 and 1954) continued the study of five-year old London children with particular reference to dental caries in relation to quality of tooth structure. Mellanby and Mellanby (1952) investigated dental disease in 14 year old London school children and compared the findings of two surveys, one in 1947 and the other in 1950. Although the purposes of these various surveys differ from that of the Edinburgh study, the data presented permit limited comparisons.

## Results

### Permanent Teeth

The mean number of decayed, missing and filled teeth for the total sample of 4,034 children is shown in Figure 4 and in A ppendix - Table IV.

FIGURE 4
MEAN DMF TEETH PER CHILD
Edinburgh School Children

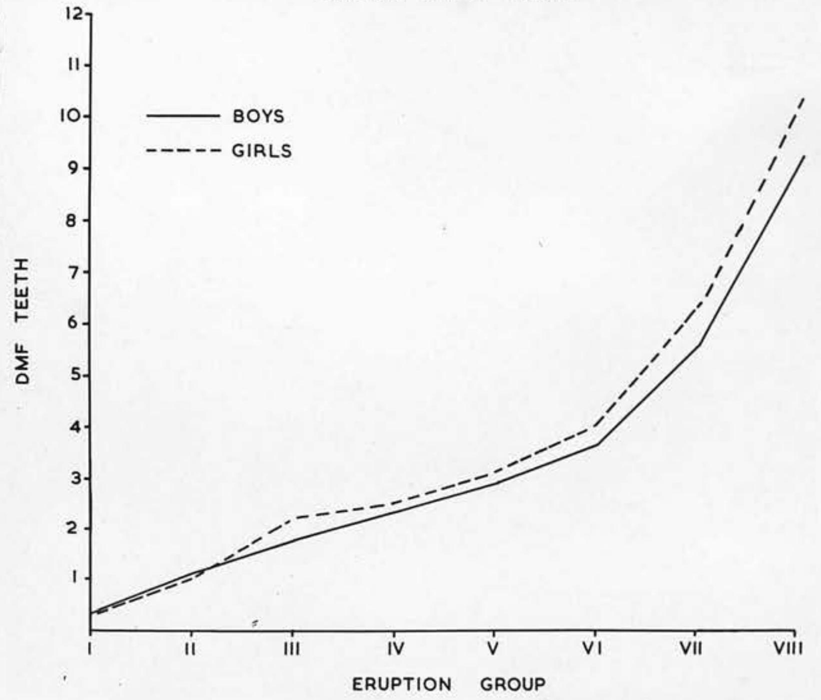



This graph illustrates the increase in dental caries experience with increase in chronological age. This increase is not, however, one of even progression, but indicates a rapid increase between the age of six and seven years, which is then followed by a slower rate of increase up to 13 years of age. From 13 years upward a more rapid rate of increase is apparent and in girls the most rapid increase occurs between 13 and 14 years; in boys the period of greatest increase in dental caries falls between 15 and 16 years.

As described in the previous chapter, the data were also arranged so that the children were grouped not by chronological age but according to the number of permanent teeth they had erupted.

In Figure 5 the mean number of decayed, missing and filled teeth for the total sample is shown graphically for the eight "eruption" groups. (See also Table V in the Appendix.)

FIGURE 5
MEAN DMF TEETH PER CHILD
Edinburgh School Children




When the incidence of caries in the individual teeth was examined for each of the groups, it was found that in the first four groups the first permanent molar contributed almost the entire amount of dental caries, while in the last four groups (V - VIII) the other teeth made an increasing contribution to the total dental caries, especially the second permanent molar. These data are presented in full in Table VI in the Appendix.

Deciduous Dentition

The mean number of decayed, missing and filled deciduous first and second molars and canine teeth in shown in Table 2 overleaf.

Table 2

The mean number of decayed, missing and filled deciduous, first and second molars and canine teeth, by age and sex, for 1,396 Edinburgh children.

| Age (years) | BOYS | | GIRLS | |
|---|---|---|---|---|
| | Number of Children | Mean Number of d.m.f. teeth | Number of Children | Mean Number of d.m.f. teeth |
| 5 years | 135 | 5.33 | 144 | 4.51 |
| 6 years | 200 | 5.64 | 170 | 5.52 |
| 7 years | 170 | 5.70 | 171 | 6.27 |
| 8 years | 204 | 6.18 | 202 | 7.14 |

The incidence of dental caries of the deciduous molar and canine teeth for each age from five to eight years inclusive is given in the Appendix in Table VII.

## Discussion

### Permanent Teeth

The data presented provide a cross-sectional picture of dental caries incidence in Edinburgh school children.

The very early onset of dental caries of the permanent teeth is of interest when it is considered that by 6½ years approximately, in spite of the limited number of teeth that can be present, 0.65 teeth in boys and 0.70 teeth in girls have been attacked.

When compared with the data presented by Mellanby and Mellanby (1952) for 14 year old London school children in 1950, certain differences are seen.

| | 14 year old London School Children D.M.F./100 teeth | 14 year old Edinburgh School Children Boys | Girls |
|---|---|---|---|
| Modern School | 13.4 | | |
| Technical School | 14.8 | 18.9 | 25.96 |
| Grammar School | 15.4 | | |

From these figures it would appear that the Edinburgh children have a considerably higher incidence of dental caries. A difficulty which arises in comparison of data relating to dental caries is that of assessing the standards of examination and criteria employed to define dental caries. For this reason precise comparison between data derived from different sources is not possible, and only an approximation can be safely considered. However, even allowing for different criteria of dental caries in these investigations, the difference between Edinburgh and London children seems too large to be explained purely on the basis of examiner difference and is suggestive of a real difference.

Mellanby and Mellanby present in tabulated form comparative figures for dental caries incidence in different parts of the world and comment that London children in 1950, with 16.1 per cent of individuals free from caries, were better than some groups.

Weaver (1950) presents data relating to dental caries incidence in North and South Shields and West Hartlepool in 1943 and 1949 for 12 year old children. Since South Shields and West Hartlepool are areas where the water supply contains natural fluoride, these figures are not comparable with those for Edinburgh children. North Shields, however, has a virtually fluoride-free water supply and it is of interest to compare the D.M.F. figures derived from this town with those for Edinburgh

The mean D.M.F. teeth per child for 12 year old children in North Shields in 1943 was 4.3, while in 1949 it had fallen to 2.4 D.M.F. teeth per child. For Edinburgh children of this age in 1951-52 the mean number of D.M.F. teeth per child is 4.4 for both sexes combined.

Data are also presented for five year old children of both sexes in North Shields examined in 1949. Converting these into d.m.f. values, it was seen that the North Shields children had a mean number of d.m.f. teeth of only 3.5. The data provide no explanation for these differences which seem too large to be explained merely on the basis of different criteria in assessing dental caries.

It is of some interest, however, to observe that the mean number of D.M.F. permanent teeth per child in Edinburgh in 1951-52 closely approximates that for North Shields in 1943. Also, that the incidence of dental caries in the deciduous dentition in North Shields in 1943, when recomputed as a d.m.f. value, is 5.0 compared with the mean d.m.f. of 4.9 for Edinburgh children in 1951.

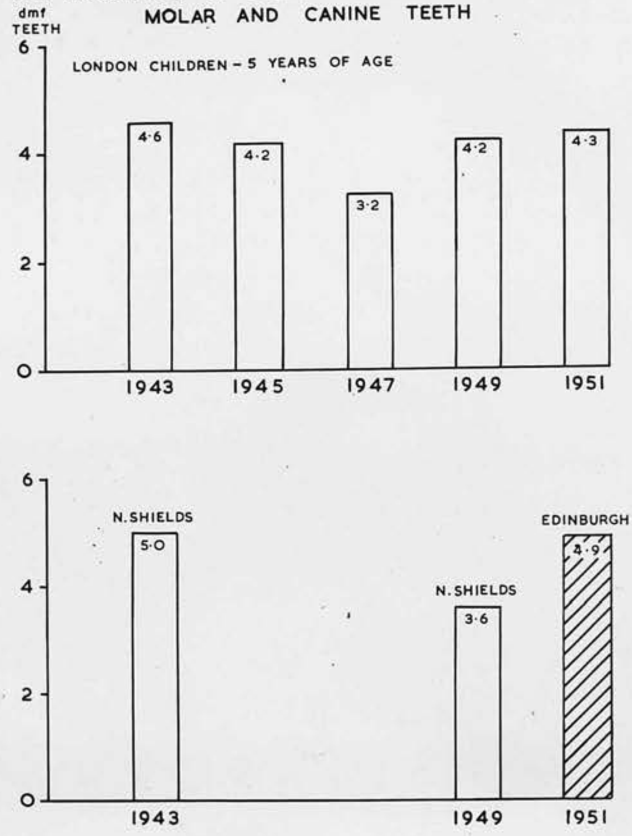
| | North Shields 1943 | Edinburgh 1951 |
|---|---|---|
| Mean D.M.F. permanent teeth per child 12 year old Children | 4.3 | 4.4 |
| Mean d.m.f. (deciduous) teeth per child | 5.0 | 4.9 |

The data relating to dental caries incidence in North Shields in 1943 and 1949 clearly reveals a marked decline in incidence over this period in both permanent and deciduous dentitions. Mellanby and Mellanby (1954) showed that in

To face p. 19.

FIGURE 6

THE INCIDENCE OF DENTAL CARIES OF DECIDUOUS MOLAR AND CANINE TEETH



five year old London children the incidence of dental caries declined steadily from 1943 up to 1947, but that by 1949 it began to increase and data obtained in 1951 indicated that the increase, although slight, continued.

It is therefore possible that:-

(a) Differences in dental caries incidence between Edinburgh and North Shields children might not have been so very different in 1949.

(b) Similarly, in 1951 the differences between Edinburgh and North Shields children might not have differed so greatly if an increase in incidence of dental caries, observed in London children, also occurred in North Shields.

The differences observed between Edinburgh children in 1951 and North Shields children of the same age in 1949 may possibly be largely a reflection of changes in the national diet which occurred during the intervening two years.

Figure 6 illustrates changes in incidence of dental caries in deciduous molar and canine teeth in 5 year old London children over the period 1943 to 1951 and those for North Shields children between 1943 and 1949. The equivalent value for Edinburgh children is shown to permit comparison.

Sex Differences in the Incidence of Dental Caries

The literature provides extensive data regarding differences in dental caries prevalence between the sexes and in respect of the permanent teeth is almost unanimous in showing the female to have a greater number of decayed, missing and filled teeth than the male at the same age. "A Survey of the Literature of Dental Caries" (1952) (Nat. Res. Coun. Washington, D.C.) cites 21 different papers in which the writers showed females to have a greater prevalence than males in the permanent dentition. Only two are cited in which no difference was found between the sexes and only one reported a higher prevalence in males.

With regard to the deciduous teeth alone, the literature is far from unanimous but the majority finding suggests that boys show a greater prevalence than girls.

Ainsworth and Young (1925), in an investigation of the dental state of children in public elementary schools in England and Wales, found no significant differences in the incidence of dental caries between the sexes for either the permanent or deciduous teeth, although in the permanent teeth the data showed a slightly higher percentage of boys with caries.

Hollanderand Dunning (1939) reported the caries incidence rates for over 12,000 adults in the age range 17 to 65 years. With only one exception the mean D.M.F. rates were higher for females than for males at all ages.

The differences in the incidence of dental caries between the sexes are not confined only to those of European origin, but havebeen reported in other races as well.

Pederson (1938), in an investigation into the dental state of Eskimos in Greenland, presented data showing that in both East and West Greenland the percentage of females with dental caries of the permanent teeth was persistently higher than that for males. Also, these differences were least in the age group 6 - 13 years and greatest in those of over 36 years of age, furthermore the differences between the sexes was more marked in West than in East Greenland. With regard to the deciduous teeth, however, in the age group 0 - 5 years females in both East and West Greenland showed a higher incidence of dental caries than the males.

Orr and Gilks (1931), in a study of two East African tribes, the Masai and the Kikuyu, found that in the Masai the proportion of boys with dental caries was 1.6 per cent, while that for girls was 3.6 per cent. In the Kikuyu, however, 13.7 per cent of boys and 13.1 per cent of girls were found to have dental caries. This near equality of the sexes in the Kikuyu children might be ascribed in part to the superior dietary adopted by custom by the women and girls of this tribe compared with that of men and boys over five years of age.

There is also evidence from earlier historical periods to indicate a difference in dental caries incidence between the sexes. Drummond and Wilbraham (1939) describe the results of an examination of mandibles from a burial ground in London known to be of the 17th century. These results showed the percentage found to be caries-free was for males 26 per cent, while for females only 14.5 per cent.

Stewart (1931) made a study of dental caries of pre-Columbian Peruvians from a collection of skulls and mandibles in the United States National Museum. He found that ante-mortem loss of teeth was clearly greater in female than in male specimens. Thus, inthe maxilla, he observed 44 per centof teeth lost in young males and 53 per cent in young females. In an older group the proportions lost were 47 per in males and 53 per cent in females. In the mandible of adult males he records the proportion of teeth lost as 47 per cent cent in males and 53 per cent in females.

Goldstein (1932), in a study of dental caries and attrition in the Eskimo, found in the skulls examined that males were more prone to caries than females and commented that this condition is unusual and that in other races caries incidence was usually reported as greater in the female.

One explanation of the sex difference in dental caries experience is attempted by Palmer, Klein and Kramer (1938), who attributed the higher caries incidence in girls to the fact that they erupted their teeth earlier than boys and in consequence have a greater total post-eruptive tooth age than boys of the same chronological ages. Since attack of the teeth by caries may be partly a function of the length of time they are exposed in the mouth, girls could therefore be expected to show a greater number of attacked teeth than boys at the same age. When boys and girls were compared according to the average number of teeth erupted, the total accumulated tooth age of boys and girls was very similar for the same number of teeth erupted.

Klein and Palmer (1938) showed that when boys and girls, who had the same total post-eruptive tooth age, were compared the dental caries experience of girls did not differ consistently from that of boys. They concluded that no significant differences in dental caries experience appeared to exist between the sexes.

Sloman (1941), however, considered that the differences in age of eruption of the permanent teeth between the sexes were insufficient of themselves to explain the greater dental caries experience in girls and postulated that, if the dental caries rates were equal in both sexes, then the differences in time of eruption of the permanent teeth would require to be greater than in fact they are.

He estimated that the average eruption dates of the permanent teeth are approximately five months earlier in girls than in boys (0.414 years). He showed from his own data that at 18 years of age boys had 24.1 per cent of all their teeth attacked by caries, while at the same age girls had 28.4 per cent. Since 24.1 per cent is the cumulative caries experience for boys by their eighteenth year, the annual increment of dental caries for each of the 12 years following the eruption of the first permanent tooth has averaged 2.01 per cent.

The age of the boys was adjusted by adding the average difference in time of eruption of the permanent teeth between boys and girls, that is, five months (0.4.4 years) and then the increment of dental caries that would be due to a further 0.414 years at the boys' average rate of annual increment was calculated and added to their total dental caries experience. This gave a theoretical cumulative caries experience of 24.9

per cent, which is still 3.5 per cent below that of girls even after the incidence rate for boys had been adjusted to compensate for the earlier eruption of teeth in girls.

He concluded, therefore, that the earlier eruption of teeth in girls did not account for more than part of their higher caries experience and if the longer period of exposure of the teeth to risk of attack by caries were the only factor, then there would have to be a difference of 2.14 years in the average age at which individual teeth of girls erupt compared with those of boys to account for the observed difference in dental caries between boys and girls at 18 years of age.

Results

From the data presented earlier it is apparent that at each year of age girls show a higher incidence of dental caries than boys. These differences are apparent in Figure 4 (p.14) and from the data presented in Table IV in the Appendix.

The differences between the sexes is sometimes explained by the observation that girls erupt their teeth earlier than boys. Table 3 (p. 24) presents the mean ages of eruption of the various teeth and also the differences in ages of eruptions between boys and girls. These data are derived from the total sample of Edinburgh children and are more fully presented in the Appendix.

From the data given in Table 3 girls can be seen to have an average age of eruption consistently earlier than boys. The differences are statistically significant for all teeth except:-

Maxillary central incisor

Maxillary and mandibular first molars

Table 3

Mean Age of Eruption of the Permanent Teeth

| Tooth | Boys yrs. | Girls yrs. | Difference in Mean Age of Eruption Boys - Girls |
|---|---|---|---|
| | | **Maxilla** | |
| $I_1$ | 7.73 | 7.69 | 0.04 |
| $I_2$ | 8.64 | 8.38 | 0.26 |
| C | 11.78 | 11.26 | 0.52 |
| $PM_1$ | 10.69 | 10.43 | 0.26 |
| $PM_2$ | 11.07 | 10.85 | 0.22 |
| $M_1$ | 6.37 | 6.30 | 0.07 |
| $M_2$ | 12.32 | 12.09 | 0.23 |
| | | **Mandible** | |
| $I_1$ | 7.01 | 6.87 | 0.14 |
| $I_2$ | 7.76 | 7.60 | 0.16 |
| C | 11.15 | 10.16 | 0.99 |
| $PM_1$ | 11.09 | 10.82 | 0.27 |
| $PM_2$ | 11.66 | 11.39 | 0.27 |
| $M_1$ | 6.41 | 6.32 | 0.09 |
| $M_2$ | 12.27 | 11.91 | 0.36 |

$I_1$ - Central Incisor

$I_2$ - Lateral Incisor.

C - Canine

$PM_1$ - First Premolar

$PM_2$ - Second Premolar

$M_1$ - First Molar

$M_2$ - Second Molar

Maxillary second molar

Mandibular second premolar

However, apart from the canine teeth, the greatest difference in time of eruption is for the second mandibular molar, which erupts on the average just over four months earlier in girls. The first molars, which make the greatest contribution to the total caries experience of children under 12 years of age, show a difference in mean age of eruption between boys and girls of only about one month.

Figure 5 (on p. 15) and Table V in the Appendix show that, when children are grouped according to the number of teeth erupted, the differences between the sexes is still evident although reduced in magnitude and suggests that these differences may be due in part to factors other than inequalities in time of eruption of the teeth.

Since the first and second molars make such a large contribution to the total caries experience, a comparison was made of the incidence of caries in these teeth in boys and girls:-

(a) when computed according to chronological age

and (b) when computed according to "dental age".

The results are presented in Figures 7, 8, 9 and 10 and it can be seen that, as expected, the difference between the sexes are reduced when children having approximately the same number of teeth erupted are compared.

FIGURE 7
THE INCIDENCE OF DENTAL CARIES OF THE FIRST PERMANENT MOLAR BY CHRONOLOGICAL AGE

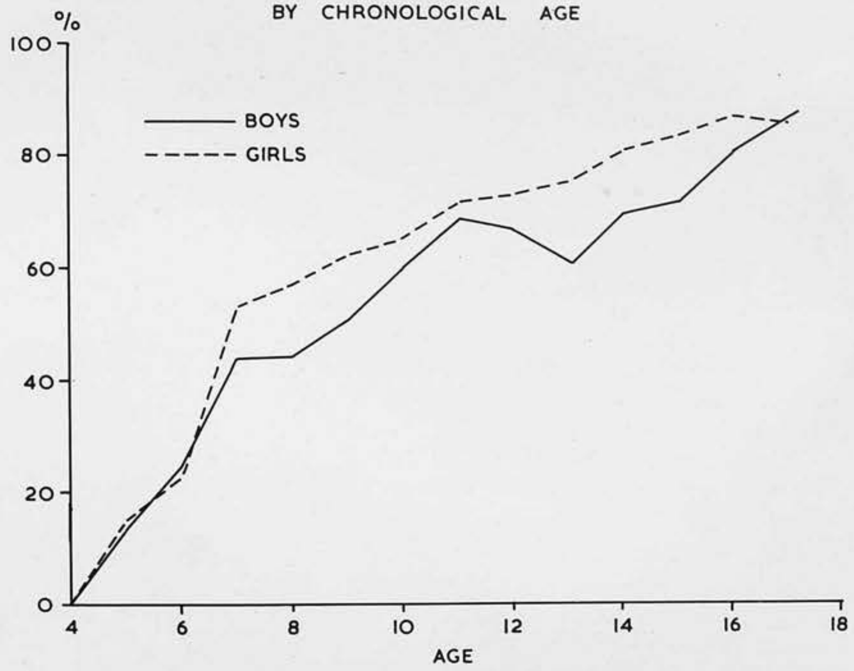



FIGURE 8
THE INCIDENCE OF DENTAL CARIES OF THE FIRST PERMANENT MOLAR ACCORDING TO THE NUMBER OF PERMANENT TEETH ERUPTED

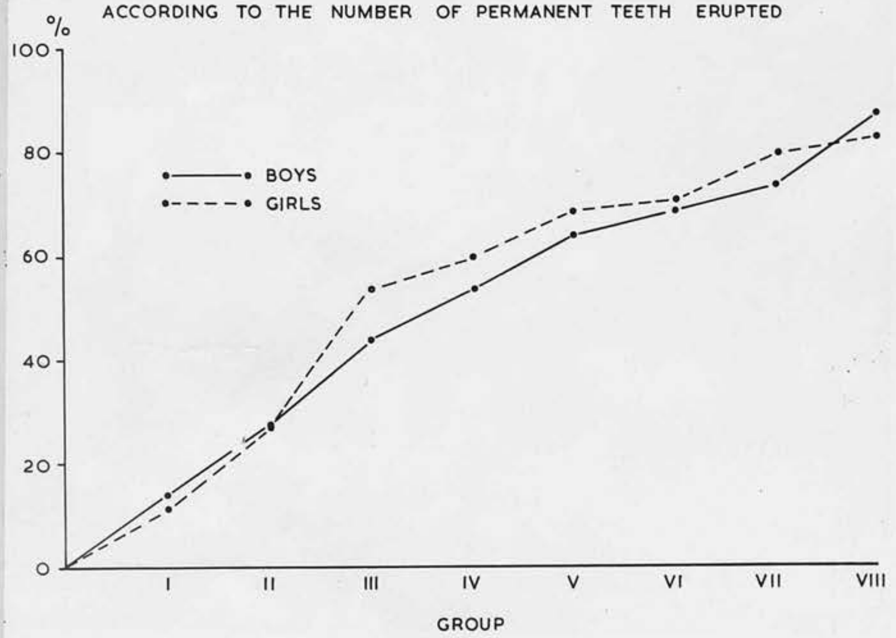


FIGURE 9
THE INCIDENCE OF DENTAL CARIES OF THE SECOND PERMANENT MOLAR BY CHRONOLOGICAL AGE

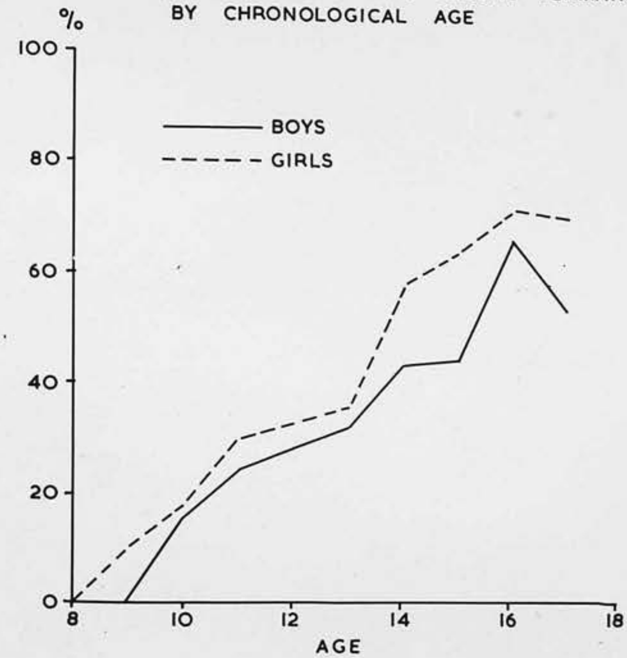
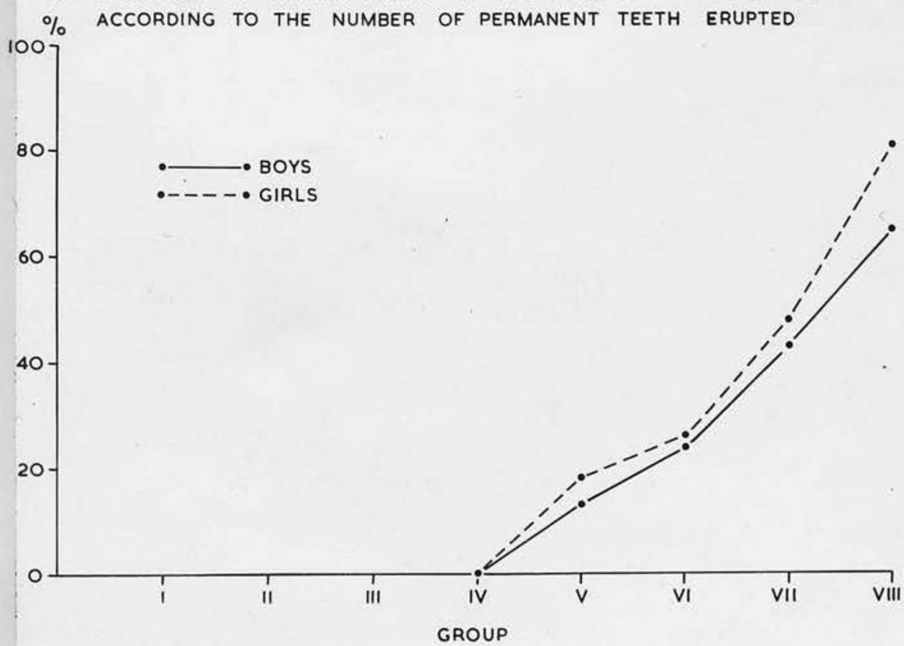



FIGURE 10
THE INCIDENCE OF DENTAL CARIES OF THE SECOND PERMANENT MOLAR ACCORDING TO THE NUMBER OF PERMANENT TEETH ERUPTED



It can be seen, however, that even when boys and girls in approximately equal stages of dental development are compared a difference in caries experience can be observed.

In order to examine the possible influence of earlier eruption of the permanent teeth in girls upon their greater observed susceptibility to dental caries, the total length of time that each tooth has been exposed in the mouth was calculated for all teeth at various ages, in terms of years of exposure. These data are presented in Table 4 below and are derived from the data relating to age of eruption of the permanent teeth as observed in this sample. (see Table 3, p. 25)

Table 4

Total accumulated years of oral exposure at ages 10, 12, 14 and 16 years

| Age | Boys | | Girls | |
|---|---|---|---|---|
| | Years of oral exposure | Mean D.M.F. per Boy | Years of oral exposure | Mean D.M.F. per Girl |
| 10.5 | 38.16 | 2.64 | 40.36 | 3.12 |
| 12.5 | 77.28 | 4.10 | 85.04 | 4.71 |
| 14.5 | 134.10 | 5.15 | 141.86 | 7.11 |
| 16.5 | 190.10 | 7.97 | 197.86 | 8.63 |

These data are presented more fully in the Appendix - Table VIII.

From these data in Table 4 it will be seen that at 14.5 years boys have a total accumulated exposure of their teeth from the time of eruption of the first permanent tooth of 134.10 years. The average rate of increment of dental caries can therefore be calculated for each year of tooth exposure;

since they have accumulated an average of 5.15 decayed, missing or filled teeth in 134.10 years of exposure of the various teeth in the mouth, the rate is .0384 D.M.F. teeth per year of tooth exposure.

The difference in average number of D.M.F. teeth per child between boys and girls of this age is 1.96 teeth and therefore boys, to achieve the same total D.M.F. as girls of this age, require an additional period of tooth exposure which at their average annual increment rate of .0384 D.M.F. teeth amount to 51.04 years (1.96/.0384).

The observed difference in total accumulated tooth age between boys and girls is 7.76 years and represents approximately only one-sixth of the additional exposure required to produce the difference which exists in average number of carious teeth actually found (1.96 D.M.F. teeth). From this it would appear that at this age the earlier eruption of teeth in girls contributes only one-sixth of the observed difference in total caries experience between the sexes, that is, 0.30 D.M.F. teeth.

Similarly, in the 16 year old children, the additional exposure required by boys to achieve the same total D.M.F. teeth as girls amounted to 15.75 years of accumulated tooth exposure. The observed differences in total tooth exposure between boys and girls, which is due to the earlier eruption of permanent teeth in girls is, as before, 7.76 years. In this age group the earlier eruption of the permanent teeth of girls contributes approximately half of the actual difference in total caries experience between the sexes and amounts to 0.32 D.M.F. teeth.

In the two younger age groups, namely the 10 and 12 year old children, the results indicated that the same general relationship existed between the actual observed differences in the total accumulated years of oral exposure of the teeth between the sexes and the hypothetical number of additional years that the boys would require before they reached an average number of decayed, missing or filled teeth equal to that of girls of the same age.

For the 10 year old children the additional period of tooth exposure that would be required by the boys in order to increase their average number of decayed, missing and filled teeth to that of girls of the same age was calculated to be 6.94 years, while the actual difference in tooth exposure between boys and girls amounted to 2.20 years.

Similarly, in 12 year old children, boys required 11.49 years of additional exposure compared with the actual observed difference in accumulated tooth exposure between the sexes of 7.76 years.

Deciduous Teeth

When the differences in dental caries experience between the sexes are examined, an interesting difference between permanent and deciduous teeth is evident. At five years of age boys exhibit a higher incidence than girls, while at six years boys and girls are almost equal and thereafter at seven and eight years girls have a greater average number of decayed, missing and filled molar and canine teeth (see Table 2, p. 16).

Discussion

The data presented are in agreement with most of the findings in the literature on this subject, in that the incidence of dental caries of permanent teeth is consistently higher in girls than boys of the same age, throughout the whole age range studied. Quite clearly this difference would appear to be a real one.

The concept that attack by dental caries may be in some way related to the duration of exposure of the teeth in the mouth is well supported by factual evidence. Namely, the regular increase in the number of teeth attacked with increase in age and also that this attack continues in the adult after the eruption of the permanent teeth has been completed.

The difference in the incidence of dental caries between the sexes has sometimes been explained in this way for since the time of eruption of the permanent teeth occurs earlier in girls than in boys, their teeth have in consequence been exposed to risk of dental caries for a longer period of time. However, when the data relating to the time of eruption of the permanent teeth are examined, the difference between boys and girls seems insufficient to account for the difference in dental caries experience observed between them. This is particularly noticeable in the instance of the first permanent molar which makes such a large contribution to the total dental caries experience up to approximately twelve years of age. With each year that passes following eruption the differences between boys and girls in time of eruption constitute an ever decreasing fraction of the total exposure. For example, girls on the average erupt their mandibular first molars 0.09 years before boys, and by ten years of age the total duration of this tooth in the mouth amounts to about four years. The difference in time of eruption contributes at this age only 1/44th of the total period of exposure. Yet the difference in the average number of D.M.F. teeth between the sexes is measurable if not large.

Klein and Palmer (1938) showed, however, that when children were compared who had the same total accumulated years of exposure of their teeth, no consistent difference in susceptibility to dental caries was found between boys and girls.

Sloman (1941), by adopting a different method of analysis, showed from his data that differences in dental caries incidence between the sexes could not be fully explained by the difference in times of eruption in boys compared with girls.

When children are grouped according to the number of teeth erupted, a better approximation to developmental age is achieved, but in this study the difference between the sexes in terms of dental caries experience is still evident, which lends further support to the view that this difference is probably due to causes other than inequalities in time of eruption.

It is difficult to reconcile the conflicting results of Klein and Palmer (1938) and Sloman (1941) and therefore, in this study, a modification of Sloman's method was adopted which also took into consideration the duration of exposure of the different teeth in boys and girls. The results obtained by this method would seem to confirm the contention that differences in time of eruption of the permanent teeth are insufficient to account for the difference in dental caries incidence between boys and girls.

The deciduous dentition provides an interesting contrast in that boys exhibit a higher susceptibility to dental caries at five years of age, but by seven years of age girls show a higher incidence of the disease.

Savara and Suber (1954) reported on the findings of the dental examination of 650 children aged six years in Portland, Oregon. Their findings also showed that at five years of age the incidence of dental caries in girls was lower than that of boys. The percentage of boys with dental caries was 81.4, that of girls 74.7.

Meredith (1946), in a review of the literature relating to the eruption of the deciduous teeth, reported that at all ages from 9 months to 2 years teeth tend to erupt earlier in males than females.

Robinow, Richards and Anderson (1942), cited by Meredith, present in tabulated form ages at eruption of the various deciduous teeth of middle and upper class Ohio children. With the exception of the deciduous first molar, boys erupted their teeth earlier than girls, but the differences between the sexes were not large. The greatest differences were for the upper canine and lower second molar, where the difference amounted to approximately five weeks. Whether comparable data would yield a similar picture for Edinburgh children is not known.

The differences in time of eruption would seem to be too small to contribute much to the observed differences in dental caries incidence. Nevertheless, the observation that boys erupt their deciduous teeth earlier than girls and that also they have a higher incidence of dental caries at five years of age, suggests the possibility that a longer period of oral exposure in boys may be related to their higher incidence of caries. If this is so, it would also indicate that susceptibility to dental caries in girls may be higher since, in spite of their early advantage, they exceed the boys in the average number of teeth attacked between the sixth and seventh year of age.

In seeking an explanation for the observed sex differences in the incidence of dental caries, the data presented here provides no ready answer beyond the fact that such a difference exists and that differences in time of eruption do not account for the total differences in caries experience.

In general, differences between the sexes can arise from (a) differences in environment or behaviour peculiar to one sex, and (b) constitutional factors, for example, differences in the pattern of growth, development, and in metabolism which are associated with the sex of the individual and which are therefore fundamentally genetic in origin.

The influence of environment upon the incidence of dental caries has been well established and supported by numerous investigations. Of the environmental factors studied, those associated with diet have been the most extensive since undoubtedly dietary factors make the greatest contribution to prevalence of this disease.

It is also generally recognised that diet can exert its effect in two distinct ways; firstly by exerting a nutritional (i.e. systemic) effect during the period of tooth development to influence the structure and quality of the dental tissues and, secondly, diet can be shown to influence susceptibility to dental caries by exerting a non-nutritional, i.e., physio-chemical effect on the intimate oral environment of the tooth itself.

If differences in dental caries incidence between the sexes are due to environmental factors, then it becomes necessary to inquire why environmental factors should operate unequally in the sexes.

The wide variations observed in individual diets, in which habit and custom play a large part, make attmepts to assess possible differences in dietary habits between the sexes difficult. On the basis of general experience no very obvious differences seem to exist.

Gustafsson et al. (1954) and many others have shown clearly that the intake of refined carbohydrates is closely related to dental caries incidence and that, in general, increase in intake of these items of diet is followed by increase in dental caries incidence.

Widdowson (1947), in a study of individual children's diets of a sample of over 1000 British children, presents data relating to total sugar consumption in all its forms by boys and girls. She shows that up to and including the age of eight years difference in sugar consumption between the sexes was negligible, but from nine years of age upwards boys consumed more than girls in increasing amounts, so that between 15 and 18 years the boys ate more than twice as much as the girls. With regard to other forms of refined carbohydrates consumed, differences between boys and girls were negligible.

On this evidence, then, differences in dental caries experience between boys and girls do not seem capable of explanation on the basis of differing consumption of known caries-producing items of diet.

In any consideration of the local oral environment and the susceptibility to dental caries, standards of oral hygiene cannot be ignored. In this instance it is of interest to compare the differences in standards of hygiene observed between boys and girls in Edinburgh.

Standards of Oral Hygiene

| | Good | Fair | Neglected |
|---|---|---|---|
| Boys | 50% | 39% | 11% |
| Girls | 65% | 30% | 5% |

The superiority of girls in this respect is clear, but a comparison of dental caries incidence in relation to standards of oral hygiene suggested that the incidence of dental caries was less amongst those whose standard of hygiene was good. It can only be concluded from this that the overall higher incidence of the disease in girls is in spite of a generally higher standard of oral hygiene.

The differences between the sexes in dental caries experience do not seem capable of explanation on the basis of environmental differences. The evidence that similar sex differences are found in past historical periods and in races such as the Eskimo in more recent times would suggest that these differences are constitutional in origin.

# CHAPTER III

## Constitutional Factors and the Incidence of Dental Caries

In the previous chapter sex differences in the incidence of dental caries were examined and, while the results provided no precise explanation of these differences, they did suggest the possibility that constitutional factors may play some part, large or small.

The literature provides considerable evidence to demonstrate the influence of diet and nutrition upon the incidence of this disease, but it is apparent also in many studies (Gustafsson et al. 1954) that certain individuals, even when subsisting upon a diet that is generally recognised to be one which tends to promote a high susceptibility, show little or no response in terms of increase in dental caries. Conversely, individuals are found in whom caries susceptibility remains high even when their diet shows a distinct lack of those substances which are regarded as caries provoking. Among the possible factors to be considered in seeking an explanation of this, the possibility that constitutional factors may be involved cannot be ignored. For this reason, then, an investigation of dental caries experience in twins was undertaken in order that an attempt might be made to obtain some measure of the possible influence that genetic constitution may have in the aetiology of dental caries.

## Review of the Literature

In contrast to the voluminous literature relating to environmental factors in the aetiology of dental caries, the literature dealing with possible inherited factors is indeed meagre.

That many tooth defects have in their origin a strong genetic basis is well established. Gates (1946) lists over forty references to literature dealing with the inheritance of tooth defects, most of which, however, relates to the inheritance of abnormalities of position in the arch, shape, size or number of teeth.

Tooth enamel is subject to genetic influence and can manifest inherited defects in degree up to complete absence. The mode of inheritance of enamel defects appears to be entirely dominant.

One of the earliest references to inheritance and dental caries is that of Sedgwick (1863), who reported a striking pedigree of early dental caries in which eleven cases, all females, occurred in three generations.

Black (1899) stated that susceptibility to this disease is influenced by heredity, age and by fluctuations of bodily condition.

In discussing the influence of heredity, he observed that "hereditary predisposition of certain families to caries has been so generally observed, that it will not be questioned and needs only mention." In support of this statement he quotes personal observations of families in which dental caries occurred in different generations at about the same age and on similar or identical surfaces of equivalent teeth. He observed, however, that when the external environment was changed, either in the mode or standard of living, or in place of residence, familial similarity became less marked. He noted, in particular, that in immigrants from Europe the pattern of susceptibility to dental caries was, in several instances, reversed between parents and children. Marked differences in the susceptibility of the parents, he considered, resulted in considerable variability among their children, some resembling one parent, some the other, but that in the majority of instances inheritance was from the more susceptible parent.

Mummery (1908) argued that racial immunity against certain diseases was the outcome of natural selection, by elimination of those most susceptible throughout the generations. He therefore postulated that the high incidence of dental caries in the artificial conditions of civilisation was to some extent due to the fact that since this disease in civilised society does not influence survival, selection ceased to operate. He supports his argument by the observation that there are individuals who are relatively or comparatively immune to dental caries, even although they share an apparently identical environment with siblings who, in contrast, suffer severely from this disease. He states as his conclusion that, since approximately 95 per cent of the population of Europe are relatively susceptible to the disease, nearly every child born, is born of susceptible parents and that any influence which the immune may exert, must soon be lost and consequently susceptibility to this disease must continue to increase.

The views expressed by both Black and Mummery can hardly be regarded as evidence that dental caries is influenced by genetic factors.

The low prevalence of this disease in primitive populations, which is sometimes advanced as evidence of racial and hence a genetic factor in dental caries, can equally be explained on the basis of environmental influence alone.

There is factual evidence, however, to show that the prevalence of the disease has increased from pre-history to the present, and Krikos (1935), making a comparison between skulls belonging to different periods of history in Greece from about 2000 B.C. to 1900 A.D., came to the conclusion that this disease has steadily increased in prevalence and still continues to do so.

There is evidence that in Britain the incidence of the disease has increased throughout history. Mummery (1907) examined skulls dating back to the Stone Age and observed only two cases of dental caries in sixty-eight skulls. In thirty-two skulls from the Bronze Age seven cases of dental caries were found, while skulls of Romans found in Britain showed evidence of dental caries in forty-one of 143 skulls examined. He also noted that, not only had the incidence of the disease increased, but that the severity of attack, as measured by the number of teeth affected per skull, had also increased.

Drummond and Wilbraham (1939) drew attention to this apparent increase in dental caries, quoting data obtained from Dr. C. M. Marant, Galton Laboratory, University College, showing that in skulls obtained from the vaults of St. Leonard's Church, Hythe, and considered to represent the population of that town between the years 1250-1650 approximately, out of 199 maxillae, 50 per cent showed evidence of dental caries. This, however, represents a considerable increase compared with evidence from pre- and early historical periods.

Colyer (1922) reported, from a study of material obtained from a burial ground in the city of London, dating from 17th or early 18th centuries, that an estimated 15 per cent of all teeth had been lost during life and that of those remaining, 10 per cent were carious. This is not truly representative, however, since of 103 carious teeth in skulls with mandibles attached, 50 were present in four specimens. It would seem from this evidence that dental caries was less prevalent in the 17th century than it is to-day, where over 90 per cent of the population suffer from this disease to a greater or lesser extent by the age of 14.

Mummery's contention that the high incidence of dental caries in civilised populations was due to the fact that natural selection could no longer operate would seem to be challenged by the observation of dental caries in apes living in natural conditions. Schultz (1944) reported that among 300 gibbons shot or trapped in North Siam, where they are found in large numbers, 20 per cent had congenital malformations of the teeth and nearly 50 per cent shot wild had some signs of tooth abnormalities similar to those in man. Dental caries was absent in juveniles but observed in 1 per cent of adults and in 9 per cent of the old animals. If dental caries was so disadvantageous to primitive man that it was removed by selection, then it is difficult to see why this mechanism has not operated in the gibbon.

The literature so far mentioned merely implies in general terms that a genetic component exists in the occurrence of dental caries.

Bachrach and Young (1927) made a comprehensive study of dental caries in identical and fraternal twins in London County Council schools. 301 pairs of twins were examined, of whom 130 pairs were classed as monozygous and 171 as dizygous. They concluded that, in respect of dental caries, identical twins are no more alike than like-sex fraternal twins. However, in regard to tooth eruption, they showed that identical twins were more like each other than the like-sex fraternal twins. The proportion of pairs of teeth in unequal stages of eruption was significantly less in the identical than in the fraternal twins. They concluded that the influence of a genetic factor appeared to be quite definite.

They also reported that, while the <u>incidence</u> of hypoplasia in permanent teeth did not differ significantly in either type of twin pair, in the identical twins the proportion in which hypoplasia was present in both twins was significantly higher than in the fraternal twins. This study will be discussed in greater detail later.

Goldberg (1930) examined the teeth of 42 pairs of identical twins and made a close study of tooth position and malocclusion. He came to the conclusion that extrinsic forces are insignificant compared with intrinsic factors in the production of malocclusion and in determining tooth position in the arch in general. From the photographs published by Goldberg, the similarity of tooth form and position between identical twins is clearly evident.

In regard to dental caries, an attempt was made to study the distribution of caries in each individual. He presents no numerical data but reports that the incidence of decay commencing on smooth surfaces was very haphazard, while that occurring in pits and fissures was more uniform. He reports that evidence of asymetry reversal could frequently be seen in pit and fissure formation, and that in a number of pairs caries was observed in corresponding teeth. He concluded, therefore, that heredity affects dental caries only indirectly by influencing tooth morphology in general and especially the formation of the pits and fissures.

Pfanner (1930) in rather more specific terms postulated that two dominant factors were concerned in immunity to dental caries, one factor (E) influencing mechanical resistance to bacterial attack, the other factor (I) producing immunity to the disease. In the cross Ee Ii x Ee Ii, the parents would have sound teeth, while the children eeII, EEii, Eeii, eeIi would have carious teeth.

Ashley-Montague (1933) reported the occurrence in identical twins of an unusual pathological condition affecting corresponding teeth in both twins in exactly the same way. Their dentitions were in all other respects remarkably alike. He also reports extensive physical data for each twin, from examination of which it is evident that, with one exception, the twins bear a remarkable physical resemblance. A photograph showing their facial features adds further confirmation of this. Full mouth radiographs, taken when the twins were six years of age, show remarkable similarity in all respects. One interesting difference observed is the presence of four fillings in one twin which are not present in the other. Evidently dental caries experience was not shared to the extent that other features were.

The main reason for this paper, however, is seen when the radographs showing the upper right second deciduous molars are examined. In both twins an unusual resorption of the distal root has occurred and in both twins the upper right first permanent molar had grown downwards and forward into the resorbed area of the deciduous molar root. By itself, this condition is unusual, but to be repeated so exactly in the other twin as well is remarkable. Ashley-Montague expresses the opinion that pressure of the erupting first molar has been responsible for the premature resorption of the deciduous molar root, and further, that environment could not have played any other than a purely incidental part, if any.

Bunting (1934), summarising the conclusions reached by the University of Michigan Research Group from the various sections of bacteriological, chemical and nutritional studies made by the group, states that during the course of the study it became very evident that heredity or individual characteristics may definitely determine caries susceptibility, irrespective of diet, since some individuals could eat any food and any quantity of sugar without increase in dental caries or in the numbers of Bacillus acidophilus in the mouth. In others, who were caries susceptible, the disease could not be checked by adherence to any ordinary diet. However, the number of individuals showing this inherent tendency to immunity or susceptibility was small. In the majority dental caries could be influenced by dietary changes.

Detlefsen (1934) considered that identical twins alone give insufficient data because their similarity may be due as much to the absence of environmental differences as to the absence of genetic differences. He suggests that analysis of correlations among other relatives gives much additional information.

He stated that, using this method to determine antero-posterior relations between the dental arches, the ratio of heredity to environment ranged from 0.9 to 1.5. From this he concluded that environment peculiar to the individual is more important than the common family environment, and therefor the importance of the genetic background in the aetiology of malocclusion is established.

A similar analysis showed that the incidence of caries is apparently non-genetic, but that extent of the disease, as distinct from incidence, seems to have a small but definite genetic basis. Later, discussing malocclusion and extraction of teeth, he concluded from an analysis of data from 4,906 white and 2,479 coloured school children, that the extent of caries in the first permanent molar appears to have a small but definite genetic background.

Gabriel (1948) made a detailed study of the morphology of all four first permanent molar teeth extracted from each of a pair of monozygous twins. Each of the four mandibular molars showed a relatively unusual feature in possessing a third postero-lingual root. A comparison was also made of six other mandibular first molars exhibiting a third root.

Five other maxillary molars of very similar morphology to those of the twins were also obtained and examined, and comparison made with the maxillary molars of the twins. The marked similarity observed between the teeth of the twins and the others suggested the possibility that these teeth were representative of a genetic type. They showed similarity, not only in regard to the extra root of the mandibular molars, but also in general morphology, colour of crown and root, clinically observable hypocalcification and dental caries. Because of this a further study was made of two hundred and thirty maxillary cental incisors and it was found possible to classify these into eighteen types. Within the individual types, teeth were found which agreed so closely with one another morphologically, that they presented a similarity approximately of the magnitude that exists bilaterally in the same mouth.

Further study of these eighteen groups showed that certain other features seemed to be associated with the type of tooth. The most obvious of these were colour and translucency of enamel, colour of root, surface texture of root, extent and colour of the stains on the teeth, facets of wear, the presence or absence of dental caries, hypocalcification of enamel, erosion, cracks or other defects in the enamel. It was stated that most, but not all, of these characters appeared to be related to structure.

Gabriel presumes that these features are basically hereditary. He observed that the dentition of the modern European shows much greater variation in morphology than that of the Australian aborigine, and suggested that this may be due to interbreeding between different white populations, with a consequent increase in gene combinations: in contrast, the Australian aborigine has been a geographically isolated race.

He cites Dobzhansky (1941) that hybridisation increases mutability, but points out that other mechanisms may exist for increasing mutation.

He further suggested that the great morphological variation seen in modern European teeth may be associated with the increase in dental caries in the past 200 years, but added that this is not to imply that the actual dissolution of tooth substance is a localised gene effect, and suggests that molecular alterations in tooth formation represent a mutant character which, in the appropriate environment, expresses itself as dental caries.

His conclusion was, therefore, that since certain types of teeth show a similar incidence of dental caries, and since tooth morphology is genetically determined, therefore susceptibility or immunity to dental caries is genetically determined, although environmental factors may precipitate or delay its onset.

Much of this is speculation and the number of teeth in each of the eighteen types described is too small to justify any firm conclusion. The greatest number in any one group is nine teeth. The author stated that these numbers are too small to permit valid statistical analysis.

Familial similarity in dental caries experience has also been the subject of a limited literature.

Klein and Palmer (1940) selected from the dental records of over 4,000 white children two groups.:-

(a) Those who had no evidence of dental caries.

(b) Those who were susceptible and were defined as those who, at age 10, had six bad or more D.M.F. teeth; at 11 years seven or more; at 12 years, eight or more; at 13 years, nine or more, and at age 14 and 15, ten or more D.M.F. teeth.

This procedure created a group of 184 immune children and another group of 117 susceptible children who had other siblings.

Two other groups were then formed, comprising

(a) Brothers and sisters of the immune children (N = 306)

(b) Brothers and sisters of the susceptible children (N = 182).

Comparison was then made between the mean D.M.F. teeth and the mean D.M.F. surfaces per child in the sibling group, by age and sex.

The data presented showed that the siblings of those children in the "susceptible" group had about twice as many teeth and tooth surfaces attacked by caries as the brothers and sisters of the "immune" group. A similar relationship was observed in respect of the deciduous teeth.

Klein and Palmer concluded that the existence of familial resemblance in the caries experience in children is definitely established, but that no specific explanation could be offered.

Klein and Shimizu (1945) reported the findings of dental examination of 3,490 Japanese married men and women residing at a War Relocation Centre in Colorado. Their data suggested that persons, male or female, who show a high susceptibility to dental caries tended to marry persons who, on the average, have a susceptibility to caries which is also high; while those with a low D.M.F. tended to marry persons who also show a low experience of dental disease.

Their method of analysis consisted of grouping both husbands and wives separately into thirds on the basis of their D.M.F. scores at a given age, that is:-

(1) One-third of the number at each age with the lowest D.M.F. scores constituted the "Low" group;

(2) One-third of the number at each age with the highest D.M.F. scores constituted the "High" group, and

(3) The remaining intermediate one-third.

In this way allowance was made for differences in age between husband and wife, since comparison was confined to the highest and lowest thirds, those in the middle third being ignored.

Examination of the data showed that the wives of men of high D.M.F. differ consistently from those of low D.M.F. The difference between the two groups of wives was seen at every age and averaged three D.M.F. teeth. A somewhat similar picture was presented when the husbands were compared on the basis of their wives' D.M.F. scores.

It was shown that wives deviated from the average D.M.F. rate for all the women combined, in the direction of their husbands' D.M.F. rating, and conversely, the men deviated from the average D.M.F. for all the men examined towards their wives' D.M.F. group. These results were found to be statistically significant.

Klein and Shimizu concluded by making an assumption that, since these differences were found at the earliest ages, these differences had existed at the time of marriage.

Examination of their data revealed that, in the youngest ages, the differences between husband and wife were not large.

While their data permit the observation that husbands and wives on the average resemble each other in terms of dental caries experience, it does not permit assumptions about their pre-marital dental state, although the possibility of such a similarity is suggested. Their comments regarding the explanation of their findings can only be accepted as speculation. Their data do, however, suggest that a shared environment, including in most cases a shared diet, may play a large part in producing a similar degree of dental disease.

Klein (1946) reported the results of examination of 1,150 families, comprising in all 5,400 individuals of Japanese extraction, at a war relocation centre in Colorado, to compare the relationship between D.M.F. rates in offspring with the D.M.F. rates in their parents. Husbands and wives were separately ranked by five year age groups into three groups each according to their D.M.F. teeth.

The first 30 per cent from the top of the rank, that is, those with the lowest D.M.F. scores, were placed in one group. The bottom 30 per cent of the rank were placed into another group, that is, those with the highest D.M.F. scores. The remaining 40 per cent constituted the middle D.M.F. group.

When the D.M.F. rates of children were compared according to the D.M.F. rates of their parents, a direct relationship was observed. Those children whose fathers had a high D.M.F. rate, had higher D.M.F. scores than those whose fathers had a middle or low D.M.F. rate. The children whose fathers had a "middle" D.M.F. rate, had a higher D.M.F. rate than the children of fathers with a low D.M.F. rate. A similar relationship was observed when children were compared according to the D.M.F. rank of mothers. This applied to both sons and daughters.

When both parents belonged to the same D.M.F. group, i.e., High, Middle or Low, the differences between the children of these three groups, boys and girls, are very marked. For example, 10-14 year old sons of parents both with low D.M.F. rates average 2 D.M.F. teeth. Daughters of the same age average 3.4 D.M.F. teeth.

In contrast, at the same age, sons of parents in the High D.M.F. group have 5.0 D.M.F. teeth, and daughters whose parents are both in the High D.M.F. rate group have an average of 6.6 D.M.F. teeth.

When the D.M.F. condition of the parents is unlike, one low and one high, the D.M.F. level of the mother has an effect on the D.M.F. level of her son about equal to that of the father. However, where daughters are concerned, the D.M.F. level of the daughter is more closely related to her mother's level than that of her father. For sons of any age, the relation to the parent with a High D.M.F. rate predominates.

Klein concluded that the remarkably consistent way in which the D.M.F. experience of offspring is related to the D.M.F. levels of parents, makes it difficult to exclude the view that susceptibility to dental disease in children involves strong familial factors which may have a genetic basis, possibly sex-linked.

Klein (1947), on the basis of his earlier work which suggested that the dental caries experience of children was closely related to the susceptibility of the parents to this disease, investigated the dental caries experience among parents and their offspring in a community supplied with drinking water containing fluoride in order to answer the question "Do children who drink fluoride water all their lives show a variation in dental caries susceptibility related to that shown by their parents.

It is well established that children living in an area where the public water supply contains fluoride in excess of 0.5 parts per million, show a reduced dental caries rate. It is recognised, however, that all children are not equally affected; some show considerable reduction in caries experience compared with similar children in a non-fluoride area; others, however, show little or no benefit, although equally exposed to the fluoride effect. This observation has been made both in this country, for example in South Shields, and in the United States of America.

The American population in which this investigation was carried out had, before 1927, a water supply which was presumed to have been fluoride-free. Therefore the parents examined in this investigation had consumed fluoride-free water during the time when they had experienced their greatest amount of dental caries. In 1927 the water supply of this community was changed to one which contained natural fluoride at a level of between 1.4 to 2.2 parts per million. In 1946, when this investigation took place, the community had had nineteen years exposure to fluoride-bearing water.

The 123 fathers and 131 mothers examined were placed into three groups according to susceptibility to dental caries. A comparison of the D.M.F. rates in the children of parents in each of the three groups showed that those children who had received the greatest protection by the fluoride water came from parents who showed the lowest susceptibility to caries, while those who received least benefit had parents whose susceptibility to the disease was high. Klein concluded, therefore, that dental caries incidence in children is determined to a certain extent by familial susceptibility. He stated that the familial factor may be constitutional in origin.

However, in animals, more precise, direct evidence has been obtainable. Hunt, Hoppert and Erwin (1944) confirmed that a coarsely ground diet of rice, powdered whole milk, alfalfa leaf meal and sodium chloride will produce dental caries in the molar teeth of rats. In order to determine whether there existed a genetic factor in susceptibility and resistance to dental caries in the albino rat, the attempt was made to produce a caries-susceptible strain and a caries-resistant strain. This work began in 1937 and was first reported in 1939. The first generation consisted of 119 rats. Of these, 16 animals produced young that were selected for brother x sister matings.

In order rapidly to produce rats, homozygous for any genes which might be responsible for susceptibility to caries, selective inbreeding by full brother x sister matings was adopted. Only those offspring developing dental caries very early after being placed on a caries-producing diet, and coming from a sibship which was very susceptible, were mated to build the susceptible strain. The resistant strain was built by full brother x sister matings, the resistant breeders being selected from resistant sibships.

The susceptible strain showed much greater homogeneity and by the 12th generation, the susceptible type was very stable.

Since the length of time taken by the progeny to develop caries was used as a measure of suitability of the parents for further breeding, the longer time taken by the resistant group before caries was manifest, resulted in longer intervals of time between successive generations. Therefore compared with the susceptible group, fewer generations of the resistant strain have been produced since breeding first commenced.

The time of onset of caries from adoption of the diet was, for the first generation, from the 15-28 day class to the 155-168 day class. The second generation resistant group ranged from 29-42 day class to the 295-308 day class. The second generation susceptible group ranged from 15-28 days to 155-168 day group.

Graphs showing the distribution of susceptible and resistant strains, from 1st to 7th generations, clearly showed the separation of the two groups from generation to generation, and revealed the declining variability in the susceptible group, while the resistant group remained variable. Variability, already low by the seventh generation, remained consistently so from the 8th to the 12th generations, suggesting that the susceptible rate had become homozygous for most of the genes responsible for very early caries.

It was noted that, in the susceptible strain, caries was not only developed more quickly, but was more severe, while in the resistant strain, caries was late in appearing and remained limited in extent. It was observed that some rats showed complete immunity.

The persistent variability of the resistant strain and its very slow movement towards greater resistance suggests that many gene pairs may be involved in determining resistance. Since the first generation was a very susceptible group, the rapidity with which the susceptible strain became stable, that is, presumably homozygous, may be explained by having many of the genes concerned in producing susceptibility at the start.

Hunt and Hoppert (1948) investigated the possibility that sex in rats might influence their resistance to dental caries. They confined their investigation to the caries resistant strain which they had developed by selective inbreeding. The susceptible strain, which they had produced by the same methods, showed so little variation that it was thought that, even if a sex difference in caries experience existed, the difference must inevitably be so small in this strain that it might not be possible to demonstrate it statistically.

The sixth to the twelfth generations of the resistant animals were used, since by the sixth generation the differentiation between the susceptible and the resistant strains had been established. This study was made of 853 male and 888 female rats.

The average time taken for the animals to develop dental caries when fed a caries-producing diet from the age of 35 days was, for males, 272.3 ± 3.6 days, and for females, 285.6 ± 3.6 days. This difference (13.3 ± 5.2 days) was 2.6 times its probable error, and was not regarded as significant.

Hunt and Hoppert considered that the data presented leaves room for suspicion that sex may sometimes be a minor factor in resistance to dental caries in albino Norway rats. Although the difference between the sexes was not significant in the conventional sense, the higher resistance of the females is consistent and no other explanation could be found to account for this difference.

Keller, Hunt and Hoppert (1954) demonstrated that when parotid ducts and portions of parotid glands were removed from a number of rats of each strain, caries-susceptible and caries-resistant, at between 35-40 days of age, the behaviour of each of the two strains in respect of caries susceptibility or resistance remained essentially the same. This suggests that the inherited difference between the caries susceptible and the caries resistant rats is not to any observable degree due to a substance or substances present in the secretion of the parotid gland.

Rosen, Benardo, Hunt and Hoppert (1955) investigated the oral bacterial flora in caries susceptible and caries resistant strains of albino rats. Differences in organisms were detected only by highly selective media for Lactobacilli and Streptococci. Lactobacillus acidophilus and Streptococcus salivarius appeared more frequently in the caries susceptible rats. Lactobacilli were not detected until the rats were about 21 days old and the frequency with which these organisms were recovered tended to increase as the susceptible rats developed caries, while in the resistant rats the frequency declined.

An unidentified Streptococcus was found in all the resistant rats examined and in 18 per cent of the susceptibles. However, although found in as large numbers in these susceptibles as in the resistant strain, the susceptible rats developed caries in the usual time on the prescribed diet.

It was considered unlikely, therefore, that this organism played any serious part in the resistance to caries shown by the resistant strain. The offspring of these 18 per cent susceptible rats also exhibited this organism and it was considered possible that heredity may influence the types of micro-organisms present in the mouths of rats.

It is apparent from the literature reviewed that there are factors in the causation of dental caries which are not satisfactorily explained by the effect of the local oral environment alone.

The evidence of familial similarity in dental caries experience is striking, but it is difficult to assess the relative parts played by a common, or at least very similar shared environment and possible constitutional factors.

In the further elucidation of this problem, twins provide valuable material for its further study.

While data derived from study of animals cannot safely be applied directly to the interpretation of similar effects in man, the evidence that susceptibility to dental caries in rats can be inherited, illustrates that such a biological mechanism can exist.

Previous Studies of Twins

Bachrach and Young (1927) made a comprehensive study of dental caries in identical and fraternal twins in London County Council schools.

The dental records obtained for study comprised 301 pairs of twins, 130 of whom were classified as monozygous and 171 as dizygous. Diagnosis of type of twin was made on the basis of:-

(a) same sex

(b) identical pigmentation of hair and iris

(c) striking overall resemblance, such that a casual observer could confuse one for the other.

Of the 171 dizygous pairs, 93 pairs were of like sex and for purposes of comparison the twins were grouped as follows:-

(1) Monozygous pairs

(2) Dizygous pairs, who were sub-divided into (a) like and (b) unlike sexed pairs.

The ages of the twins ranged from 3 to 14 years, and the mean age in each of the groups was approximately 9 years. These authors stated that there was no significant difference in mean age or variability in age in the twins comprising the four groups.

A comparison of the overall incidence of dental caries between the four groups was made by calculating correlation coefficients between the numbers of carious permanent teeth in the pairs of twins in each of the groups.

Since the number of carious teeth in any group increases with age, and since the regression of carious teeth on age is approximately linear, the partial correlations between dental caries in the twin pairs, with age held constant were obtained. The results showed that no significant differences in incidence of dental caries existed between monozygous and like-sex dizygous pairs, and the writers interpreted these findings as suggesting that heredity played a minor part in the incidence of dental caries.

The data on dental caries in deciduous teeth in pairs of twins were similarly analysed. Children over 9 years of age were excluded. However, little importance was attached to the results by the authors, who stated that a large proportion of possibly carious deciduous teeth have been lost from natural causes. This statement obviously refers to the deciduous incisor teeth and it is also evident that missing deciduous molars were not counted as having been carious, although such an assumption is manifestly reasonable for children under nine years of age. It is interesting to note, however, that in spite of this, the monozygous pairs show a higher correlation than the two groups of dyzygous pairs.

With regard to individual teeth, the first permanent molar was the only tooth in which an analysis was made. Corresponding teeth were compared between twins, recording occlusal caries only, but recording in addition, three degrees of caries. In this way, ten categories were created to which the corresponding pairs of molars could be allotted, i.e.,

(i) Both of the pair non-carious

(ii) One non-carious, the other carious - degree 1, 2 or 3.

(iii) Both carious, both with caries degree 1<br>
one with degree 1, other with degree 2<br>
both with degree 2<br>
one with degree 2, other with degree 3<br>
both with caries degree 3.

The numbers of pairs of first molars in these categories were expressed as a percentage of the total number of pairs of teeth. The total percentages of these pairs showing discordance between them in respect of dental caries were compared between the four groups and, although slightly less in monozygous pairs when compared with the dizygous groups, the differences were not significant.

Statistical tests to measure the degree of association between the twins showed higher values for monozygous than for like-sex dizygous pairs, but the statistical difference between these two groups were not considered of such degree as to be regarded as significant.

Dahlberg and Dahlberg (1942) investigated dental caries incidence in monozygous and dizygous twins. The group investigated was relatively small, containing in all 126 pairs of twins, of whom 37 pairs were monozygous and 89 pairs dizygous. Of the dizygous pairs, 44 were like-sex pairs and 45 unlike-sex pairs. The mean age of the monozygous pairs was 9.9 years, while that of the dizygous pairs was 10.3. Dahlberg and Dahlberg regarded the differences in age as being negligible. These values for age correspond closely to those for the Edinburgh twins.

With regard to the incidence of dental caries, they also showed that there was no important difference in degree between monozygous and dizygous pairs. The percentage carious for all teeth was for monozygous twins 24.8 per cent, for dizygous like-sex 25.8 per cent, and for dizygous unlike-sex 28.7 per cent.

In their analysis of the data, teeth were divided into maxillary and mandibular, and these further divided into right and left sides. They further divided the teeth into two groups for each quadrant of the mouth. Incisors and canines formed one, premolars and molars the other group. Tooth for tooth comparisons were made between members of a twin pair, i.e., corresponding teeth on equivalent sides of the same jaw were compared: this was done for both types of twin. No attempt was made to assess degree of caries, such as was attempted by Bachrach and Young, since, as Dahlberg and Dahlberg state, the results must in any case be approximate. They therefore considered it was not valid to apply other criteria of similarity to the data (presumably meaning site of lesion and degree).

They regard the unit of one carious tooth as the safest basis for judgment. Nehls (1940), cited by Dahlberg and Dahlberg, has used the set of teeth as the unit for analysis. To compare their findings with that of Nehls, Dahlberg and Dahlberg assessed the frequency of "concordance" and "discordance" according to Nehl's criteria. They observed that in 37 monozygous twins, 28 cases of concordance and 9 of discordance, while in the 44 dizygous like-sex twins, 37 cases of concordance and 7 of discordance.

In 45 dizygous unlike-sexed pairs, 27 cases of concordance and 18 cases of discordance were observed.

Altogether, 28 per cent of all dizygous cases were discordant, compared with 24 per cent of monozygous. Therefore, Nehl's observation that there is a very substantial difference between monozygous and dizygous twins is not supported by the observations of Dahlberg and Dahlberg in their study.

Using as the unit "one carious tooth", and making a tooth by tooth comparison between twin pairs, Dahlberg and Dahlberg computed mean values for the two groups of teeth, i.e., the incisors and canines, and premolars and molars. Missing permanent teeth, which had been extracted because of dental caries were included as carious. Deciduous teeth were not included.

Three categories of carious experience were recognised - Both non-carious, Both carious, and One carious. For each category expected values were calculated for the numbers of tooth pairs which could be expected to occur in each category purely by chance. In the calculation of these expected values, the formula used was that used by Dahlberg, G. (1926) in a study of mortality of twins at birth. The observed and expected values were tabulated for the two tooth groups and also for all teeth together.

In the category "Both teeth carious", observed values considerably exceeded the expected, while in the category "one tooth carious" the observed values were very markedly smaller than the expected. In the category "neither" of the pair carious, the disparity between observed and expected values is less marked, but the observed values for all twins exceeds the expected.

The distribution of tooth pairs into these three categories then, are obviously very different from what could occur by pure chance alone.

The differences between monozygous, like-sex dizygous and unlike-sex dizygous twins do not therefore appear to be very great in this work.

The authors regarded the differences between monozygous and like-sex dizygous as insignificant. However, from the numbers of tooth pairs in the categories "neither carious" and "both carious" probabilities for the comparative values of genetic and environmental factors were calculated from mathematical formulae. From the calculated probabilities the authors conclude that inherited factors are at least half as important as environmental factors and at most of equal importance.

Brucker (1944) made a detailed study of six pairs of monozygous twins and compared their dental caries experience. The small number of pairs and the great disparity in age (they ranged from 5 years to 23 years) made any statistical analysis of this data impossible. The dental case histories for each pair were presented, compared and discussed.

# CHAPTER IV

## Heredity and Dental Caries

Fraser Roberts, in his preface to "An Introduction to Medical Genetics", writes, "There is probably no teacher of medicine who does not stress the importance of hereditary constitution as one of the factors to be considered in discussions on the causation of disease."

This present study was undertaken to obtain information regarding the dental caries experience of identical and fraternal twins, and by comparison, to attempt to assess the relative importance of heredity and environment as factors in the causation of this disease in Edinburgh school children.

Further, comparison of both types of twins with comparable pairs of unrelated children was undertaken, in order to discover whether the unrelated pairs of children would show inter-pair differences in their dental state, of a different magnitude to either or both the identical or fraternal pairs.

In this way it was hoped that it might be possible to distinguish genetic, familial and purely environmental influences in the production of dental caries, and to obtain some indication of their magnitude and possible significance.

### General Considerations

Human twins are of two kinds, fraternal and identical. The first kind arise as the result of simultaneous fertilization of two separate ova which have matured and have been shed at the same period in time. Genetically, the two embryos which develop are no more alike each other than are other siblings born separately. They are, in fact, normal siblings born at the same time.

The second kind of twins, however, are derived from a signle fertilised ovum, which splits into two very early during development, producing two separate individuals. Since identical twins are derived from a single fertilised ovum, they have precisely the same total genetic constitution and as such are, genetically speaking, duplicates one of the other. They must therefore be of the same sex and, in fact, so resemble each other in physical appearance that they are difficult to identify apart, even by friends and sometimes even by parents.

Any observed differences between the one-egg, or monozygous twins of a pair must clearly be environmental in origin, whilst differences between members of a two-egg or dizygous pair, can be compounded of both environmental and genetic influences. The comparison of similarities and dissimilarities in respect of any particular trait in monozygous and dizygous pairs may therefore provide valuable information as to the extent to which the trait in question is determined by inherited or environmental factors.

For those characters which are entirely determined by heredity, e.g., blood group, monozygous twins must show complete concordance, while dizygous twins may or may not resemble each other, and do so with a frequency neither greater nor less than ordinary siblings born at different times.

There is, however, another complicating factor which enters into any comparison of differences between the individuals of a monozygous twin pair. In those monozygous twins where division of the single fertilised ovum has occurred relatively late, reversal of certain physical features, which are normally asymmetrical may occur. For example, reversal of handedness, one twin being right-handed, the other left-handed. Other characters which are commonly reversed are the occipital whorl of hair, which may in one twin be clockwise and in the other anti-clockwise. Irregularities in dentition are sometimes observed in which they appear on opposite sides in the two twins. Extreme examples of late division of the ovum are the appearance of Siamese or conjoined twins, who are usually much less alike than normal, separate, identical twins.

Since, in the development of the normal single embryo, the two lateral halves begin at a point of time to assume different rates of growth, lateral asymmetry is a characteristic possessed by all individuals. Therefore, even although marked reversal of asymmetry or mirror-imaging does not occur, monozygous twins can show considerable differences in certain physical characteristics, due to the occurrence of the twinning division at varying periods after the establishment of different rates of growth in the single embryo. This then can account for differences at birth of features such as height and weight which are frequently observed.

It is, however, recognised that differences observed in monozygous twins at birth can be, and in all probability frequently are, due to differences in their prenatal environment. In utero, their blood supplies are never precisely identical and differences in rates of growth can be expected for this reason alone. Further, the possibility exists that any such prenatal advantage gained by one of the monovular pair may be to some extent at the expense of the other twin and thereby widens the differences between them.

From birth, however, the total environment of monozygous pairs can be assumed in general to differ neither more nor less than does the environment of dizygous pairs. In this study it is assumed that post-natal environmental differences between members of twin pairs are approximately equal, whether the pairs are monozygous or dizygous.

Diagnosis of Type of Twin

Similarity Method

Since monozygous twins must have identical genetic constitution, they must be identical in all physical characteristics which are entirely genetic in their determination. Dizygous pairs, on the other hand, are no more alike than ordinary siblings, with the exception that, being of the same age, they may more resemble each other than ordinary siblings separated by a year or more in age. However, physical differences are observed in monozygous twins, and have their origin in such events as reversal of asymmetry and prenatal environment.

Since the theoretical possibility that dizygotic twins could inherit identical genotype is remote in the extreme, the danger of diagnosing dizygous as monozygous twins is negligible. However, due to factors which can operate during development to modify the physical expression of their identical heredity, the possibility of classifying less similar monozygous pairs as dizygous is a real one.

Newman, Freeman and Holzinger (1937) describe their criteria for classifying monozygous twins as follows:-

(1) They must be so strikingly similar in general appearance that they are likely to be mistaken the one for the other.

(2) They must be essentially identical in hair colour, hair texture and hair form.

(3) They must have essentially the same eye colour and pigment pattern on the iris.

(4) They must have the same skin colour, unless one is modified by tanning, and the same amount and distribution of body down, especially on face, neck and hands.

(5) They must have essentially the same facial features - nose, lips, chin and ears.

(6) They must have essentially the same types of teeth, the same irregularities in dentition.

(7) They must have hands and fingers of the same type and proportions.

(8) The general microscopic character of the friction ridges of fingers and palms must be essentially the same.

(9) There must be a stronger cross-resemblance than internal resemblances in most of the details of finger and palm patterns. (One hand of one twin must be more like the corresponding hand of the other twin, than like his own other hand.)

(10) The presence of reversed asymmetry (mirror-imaging) in handedness, hair whorl, dentition, palm patterns, etc. is confirmatory evidence of monozygous origin, but its absence does not deny it. Neither does the presence of left-handedness or counter-clockwise hair whorl in one of a pair of decidedly unlike twins, indicate that they are monozygous.

Finger Print Method

Stocks (1930), in a study of 230 pairs of twins of both kinds, proposed that if a pair of twins satisfies the requirements of physical resemblance demanded by the similarity method for monozygous twins, comparison of their finger-prints will make diagnosis practically certain. His method is as follows.

A comparison is made of similar patterns found on the ten fingers of the right and left hands of the two individual twins. A pair of fingers is classed as similar, not only in respect of the same class (i.e. arch, whorl or loop), but as alike as regards general pattern, inclination of axes, position of deltas and numbers of ridges as to make them appear the same on examination, without actually making ridge counts or comparing other minute detail.

Stocks observed that all twins diagnosed as monozygous on the basis of physical resemblance showed not less than six corresponding fingers alike between the individual twins of a pair - a value which was at least equal and more usually greater than the resemblance between right and left hands of the same individual.

He found no sex difference in finger prints, and therefore the comparison between the fingers of unlike-sex pairs was taken to represent the range of resemblance to be expected in all dizygous twins.

He observed no more than six fingers alike in unlike-sex pairs of twins and that out of 25 unlike-sex pairs, only three pairs showed as many as six fingers alike.

Newman, Holzinger and Freeman, however, concluded that the observation of seven or more corresponding finger-prints in a pair of twins would make the diagnosis of monozygous twins certain.

Methods of Classifying Twins in the Edinburgh Study

Similarity Method

In this study, nine physical features were compared for each pair examined, together with an assessment of overall appearance. The characters compared were:- Nose, lip and chin shape; hair colour and texture; eye colour (including consideration of iris pattern); hands, shape and proportions including nails; ears; tooth colour and shape. For those features which are bilateral, i.e., hands and ears, a double comparison was always made. The right of one twin was compared with the right of the other twin, and the left of one with the left of the other; then the opposite sides were compared, i.e., right of one with the left of other and *vice versa*. This was done as a routine in twins to make allowance for reversal of asymmetries. These characters, together with "General Appearance", made up twelve categories and the findings in respect of these were recorded under the headings "Identical", "Similar" and "No Similarity". To obtain a numerical assessment of these, a value of 2 was allotted to each feature under the heading "Identical", and a value of 1 to each feature recorded under the heading "Similar". Hands and ears, as bilateral characters, contributed four categories in all. No value was allotted to any feature recorded under "No Similarity".

Since "Identical", "Similar" and "No Similarity" are in respect of any one feature mutually exclusive, the total score possible for complete identity of the characters studied was 24.

The scores for physical resemblances were then expressed as a percentage. This was done to allow comparison in those instances where injury or illness either prevented comparison of certain features, or rendered any particular comparison valueless. For example, one pair was examined in which one had suffered facial injury. In another instance, injury to one hand of a twin did not permit comparison of hands in that pair (although finger prints were obtained).

Finger-print Recording

Prior to the commencement of this study, permission was sought and obtained from the Chief Constable to receive some instruction in the techniques of recording and classifying finger-prints, from the officer in charge of the Finger-print Section of the Edinburgh City Police. Instruction from this source also included information as to the correct equipment and material to use.

Interpretation of Finger-prints

Each print was examined with a hand-magnifying glass and compared with the corresponding print for the other twin. Stocks' criteria of similarity were adopted and prints were classed as similar not only in respect of type, e.g., arch, whorl or loop, but so alike as regards general pattern, inclination of axes, position of deltas and apparent numbers of ridges as to make them appear the same on examination. However, in a small proportion of twins, ridge counts were actually made where difficulty was encountered in deciding similarity for any particular print.

Each finger-print was compared with the corresponding finger-print of the other twin, then when all ten sets had been compared, each print was again compared with the corresponding print from the other side of the second twin, that is, right of one twin compared with the right of other, left of one with left of other, then right of one compared with left of other and vice versa. In this way "mirror-imaging" was allowed for and in some instances a low correspondence, obtained when corresponding sides were compared, showed a high correspondence when prints from opposite sides were compared.

Finally, a comparison was made of finger-prints of right and left hands of each member of the pair separately, to obtain a value for "internal" resemblance.

No pair was accepted as monozygous unless the value for external resemblance between both twins exceeded the value for internal resemblance between each twin's own hands. In general, then, twins were only classed as monozygous when they showed seven corresponding finger-prints alike out of the ten possible.

Exceptions to this rule occurred in ten pairs, where six corresponding finger-prints out of ten were accepted because of a very high physical resemblance; and in four pairs internal and external resemblance were equal, but these were accepted because of 100 per cent physical resemblance.

The finger-prints of 220 of the twin pairs were examined, classified, and a score allotted for degree of correspondence between corresponding fingers, but in no instance did the finger-print assessment necessitate changing the provisional diagnosis (made from the data on physical resemblance) of monozygocity. Finger-print scores did, however, enable the classification of some twenty pairs about whom some doubt existed.

The distribution of all twins by age, sex and twintype is given in Table 5.

Table 5

Distribution of like-sex twins by age, sex and type of twin
Total like-sex Twins N = 224

| Age | Monozygous | | Age | Dizygous | |
|---|---|---|---|---|---|
| | M | F | | M | F |
| 5 | 5 | 2 | 5 | 4 | 4 |
| 6 | 9 | 8 | 6 | 14 | 8 |
| 7 | 4 | 11 | 7 | 9 | 10 |
| 8 | 4 | 5 | 8 | 5 | 6 |
| 9 | 6 | 2 | 9 | 3 | 5 |
| 10 | 8 | 4 | 10 | 9 | 9 |
| 11 | 6 | 6 | 11 | 12 | 10 |
| 12 | - | 2 | 12 | 1 | 1 |
| 13 | 1 | 3 | 13 | 5 | 3 |
| 14 | 1 | 6 | 14 | 3 | 3 |
| 15 | 1 | 1 | 15 | 1 | 1 |
| 16 | 1 | - | 16 | 1 | - |
| 17 | - | - | 17 | 1 | - |
| Total | 46 | 50 | Total | 68 | 60 |

All Twins: M = 114 F = 110

Total Monozygous = 96

Total Dizygous = 128

Ratio **Mz** : Dz = 0.75

Newman et al. (1937) referring to the findings of J. B. Nichols in a twin population of 717,907 pairs, show a ratio of monozygous to dizygous same-sex twin-pairs of 0.72.

The closeness of the ratio for Edinburgh twins to that given by Nichols for a remarkably large twin population, leads to the conclusion that any errors in diagnosing twin type in Edinburgh twins are negligible.

In Tables 6 and 7 the findings in respect of physical resemblance and values for finger-print correspondence are given as means for each age and the mean for the whole group for monozygous and dizygous twins.

Cross resemblance in finger-prints is the resemblance between corresponding fingers of each twin, while internal resemblance is the resemblance between right and left hands of the individual twin.

Physical Resemblance and Fingerprint Correspondence

Table 6 : Monozygous

| Age | Mean Physical Resemblance | Fingerprints | |
|---|---|---|---|
| | | Cross Resemblance | Internal Resemblance |
| | % | | |
| 5 | 90.85 | 7.57 | 3.86 |
| 6 | 90.63 | 7.23 | 3.40 |
| 7 | 91.15 | 7.55 | 5.58 |
| 8 | 95.83 | 7.88 | 5.13 |
| 9 | 93.23 | 7.63 | 6.13 |
| 10 | 86.11 | 7.48 | 5.13 |
| 11 | 92.36 | 7.37 | 5.04 |
| 12 | 100.00 | 6.50 | 5.00 |
| 13 | 89.58 | 7.00 | 4.25 |
| 14 | 88.41 | 7.29 | 5.00 |
| 15 | 83.33 | 7.00 | 2.00 |
| 16 | 100.00 | 7.00 | 2.00 |
| 17 | - | - | - |

Mean physical resemblance for whole group = 21.72 = 90.96%

Fingerprints: Mean cross resemblance for whole group = 7.43
Mean internal resemblance for whole group = 4.73

Table 7 : Dizygous

| Age | Mean Physical Resemblance | Fingerprints | |
|---|---|---|---|
| | | Cross Resemblance | Internal Resemblance |
| | % | | |
| 5 | 16.16 | 1.82 | 6.36 |
| 6 | 27.79 | 2.51 | 4.82 |
| 7 | 23.90 | 1.81 | 5.13 |
| 8 | 14.39 | 2.09 | 6.09 |
| 9 | 29.16 | 1.50 | 5.25 |
| 10 | 23.59 | 1.74 | 5.45 |
| 11 | 24.51 | 2.50 | 6.45 |
| 12 | 27.08 | 2.00 | 3.00 |
| 13 | 11.97 | 2.82 | 4.87 |
| 14 | 36.80 | 2.00 | 4.07 |
| 15 | 8.33 | 1.00 | 7.50 |
| 16 | 41.66 | 2.00 | 5.00 |
| 17 | 25.00 | 3.00 | 5.00 |

Mean physical resemblance for whole group = 5.58 = 23.83%

Fingerprints: Mean cross resemblance for group = 2.12
Mean internal resemblance for group = 5.47

Reversal of Asymmetry

Handedness

An attempt was made with each pair to determine whether a twin used the right or left hand. In children under seven years, and for those older children about whom some doubt existed, the decision regarding handedness was made on the basis of performance of simple tasks by the twins, for example being asked to lift and hand over an object, open or shut a door, or by throwing an object. The results obtained are shown below.

| | Monozygous | | Dizygous | |
|---|---|---|---|---|
| | N. | % | N. | % |
| Both right-handed | 89 | 92.7 | 122 | 95.3 |
| One left, the other right-handed | 6 | 6.3 | 5 | 3.9 |
| One ambidextrous, one right-handed | 1 | 1.0 | 1 | 0.8 |
| | 96 | 100 | 128 | 100 |

Examination of finger-prints revealed reversal (that is right hand of one twin resembling left hand of the other) in 13 pairs of monozygous and none in dizygous twins.

Reversalof finger-print patterns was present in all of the seven pairs who exhibited reversal of handedness. Six pairs therefore revealed reversal of finger-prints but no reversal of handedness. A careful examination of the dental records of these children failed to reveal any clear evidence of reversal in pattern of dental caries. In the tooth by tooth comparisons, therefore, the question of possible reversal of comparable teeth was ignored.

Methods

The twin pairs, having been separated into monozygous and dizygous groups by the methods already described, it was necessary to consider the sub-grouping of the two groups.

On examination, the individual twins of a pair had been designated as "Twin A" and "Twin B" on the basis of the alphabetical order of their Christian names. However, the decision to group the twin pairs by number of teeth erupted produced a difficulty in the form of differences in number of teeth erupted in individual members of a twin pair, for example, Twin A having eight permanent teeth erupted, while Twin B had nine permanent teeth erupted. The decision had then to be made as to the sub-group into which the twin pair would be placed.

Since it was intended that a comparison should be made between equivalent teeth in each twin of a pair, then obviously such comparison could only be made for those teeth which both twins had in common. For this reason, then, the twin pairs were allotted to the sub-group appropriate to the individual twin with the smaller number of teeth erupted. In the example given above, the twins as a pair would be placed in the group having 5 - 8 teeth erupted, since the additional tooth possessed by B could not in any case be compared.

The designations "A" and "B" were therefore reallocated so that the twin with the lesser number of teeth erupted (the "registration" twin) now became twin "A".

Control Groups

The object of the study was to compare similarity of dental caries experience in monozygous and dizygous twins, and also to compare the experience of unrelated pairs of children with each type of twin in respect of this disease. A control group was therefore created by selecting for each "A" (or registration) twin the dental record of a child of the same sex and having as nearly as possible the same age and same number of teeth erupted. These "control" children were selected from a large sample of Edinburgh children examined during the previous years. In the age range 5 - 14 years there was for every twin a choice of several children suitable for matching and therefore the child was randomly selected. Above 14, however, greater difficulty was met in selecting the control child, and in some instances no choice was available, there being only one child eligible for selection. This situation had to be accepted.

Each "control" child so selected was then paired with the "A" twin to create a pair of children in no way related but as alike as they could be made in respect of age and sex and having a difference in the number of permanent teeth erupted no greater than had existed between twins A and B. The variable not held constant was their dental caries experience.

Four groups were thus created, the monozygous twins, the dizygous twins and two groups of unrelated pairs, one matched with the monozygous twins "A", the other matched with dizygous twins "A."

The two control groups have been designated the "monozygous control" and the "dizygous control" groups. In the tables following, the symbols MZ/C and DZ/C are used to identify these groups.

Because of the small numbers of twins, it was decided not to separate the sub-groups into males and females, but to combine the sexes. A lthough this procedure is not ideal, the comparisons to be made are of the <u>differences</u> between members of a twin pair and since only like-sex pairs were chosen, it was considered that this grouping of male and female pairs together within their particular tooth-eruption group would not entail serious error.

Table IX (in Appendix) indicates that both the monozygous and dizygous twins have been adequately matched with an unrelated child to produce a control group of unrelated pairs entirely comparable with the twins in terms of age. This table also permits comparison of monozygous and dizygous twins in respect of age by each group and with the values for the total sample of Edinburgh children, given in Table III in the Appendix.

The differences observed between the mean ages of the monozygous and dizygous twins in each group are not significantly different, and are found to lie well within the standard error of the large population sample.

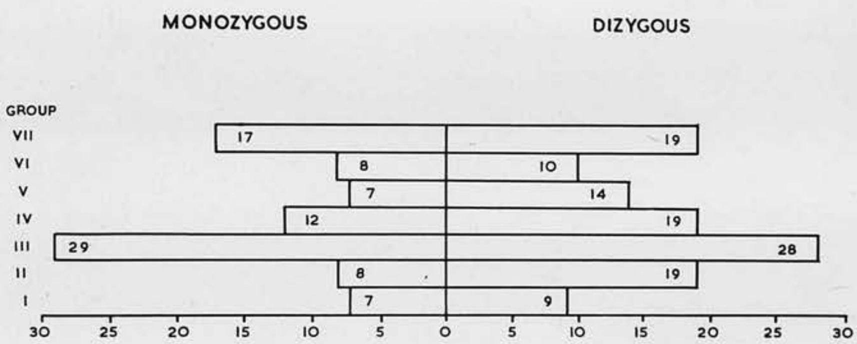
While the immediate objective of this study was to determine the similarity in dental caries between monozygous twins and compare it with that found between dizygous pairs, an examination of the basic data revealed that a direct comparison between the two types of twins would be fraught with considerable uncertainty for several reasons.

Firstly, the numbers of twins in each of the sub-groups were too small to justify a group by group comparison, and therefore amalgamation of some or all groups would be necessary to permit of analysis.

Secondly, the distribution of twins throughout the various sub-groups showed considerable differences between the two types of twins, with the result that attempts to create sizeable groups by amalgamation of two or more sub-groups could only result in considerable heterogeneity between the two types of twins compared in respect of number of teeth erupted. Figure 11 illustrates the distribution of twins throughout the various "tooth eruption" groups.

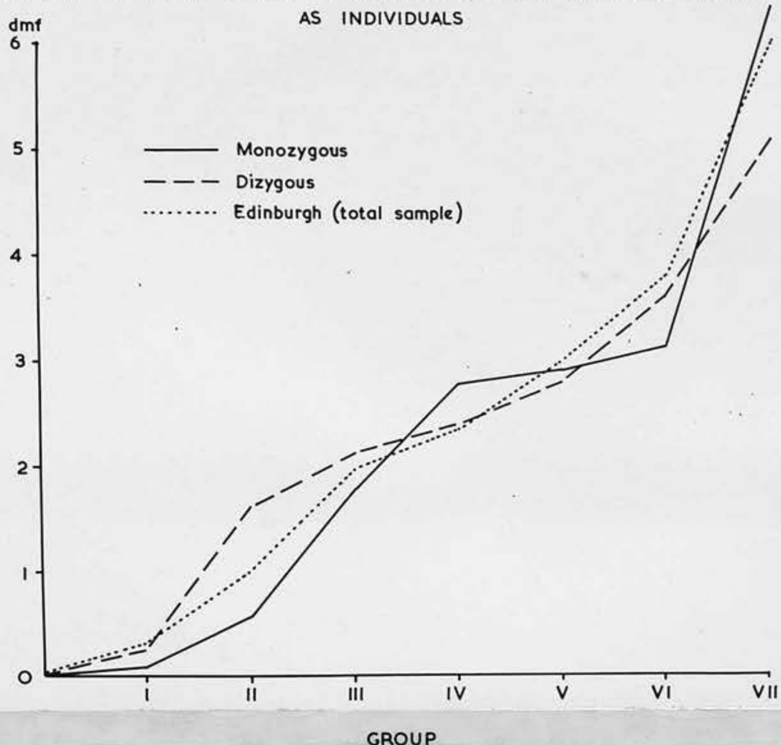
FIGURE II

NUMBER OF TWINS AT DIFFERENT STAGES OF TOOTH DEVELOPMENT




Thirdly, differences existed in the incidence of dental caries between monozygous and dizygous twins and in one sub-group (Group II) these differences were found to be statistically significant for the permanent teeth. Figure 12 illustrates the incidence of dental caries in the two classes of twins, together with that of the total Edinburgh sample.

FIGURE 12
DENTAL CARIES INCIDENCE IN MONOZYGOUS AND DIZYGOUS TWINS
AS INDIVIDUALS




These data are also presented in the Appendix - Tables IX, X and XI.

The difficulties inherent in a direct comparison of the twins were avoided by making use of the control groups to provide a method of indirect comparison. In this way the monozygous and dizygous twins could be compared directly with their own matched control and then finally the differences between each type of twin and their controls compared.

Since the structure of the twin and their respective control groups were virtually identical in regard to numbers, age, sex and number of teeth erupted, it was therefore possible to amalgamate all the sub-groups and treat the twins as single groups, thus overcoming the difficulty of inadequate numbers. In this way four groups were created, the two twin groups and the two control groups.

Figures 13 and 14 illustrate the incidence of dental caries in the twin and control groups (for this purpose the twins and controls have been treated as individual children, not as pairs).

To face p. 83.

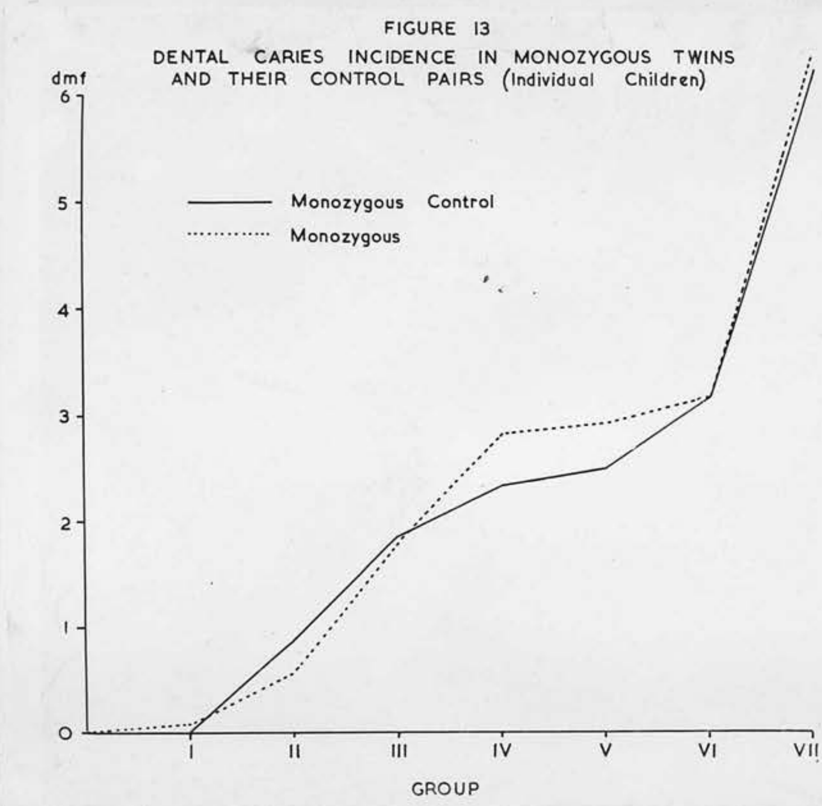
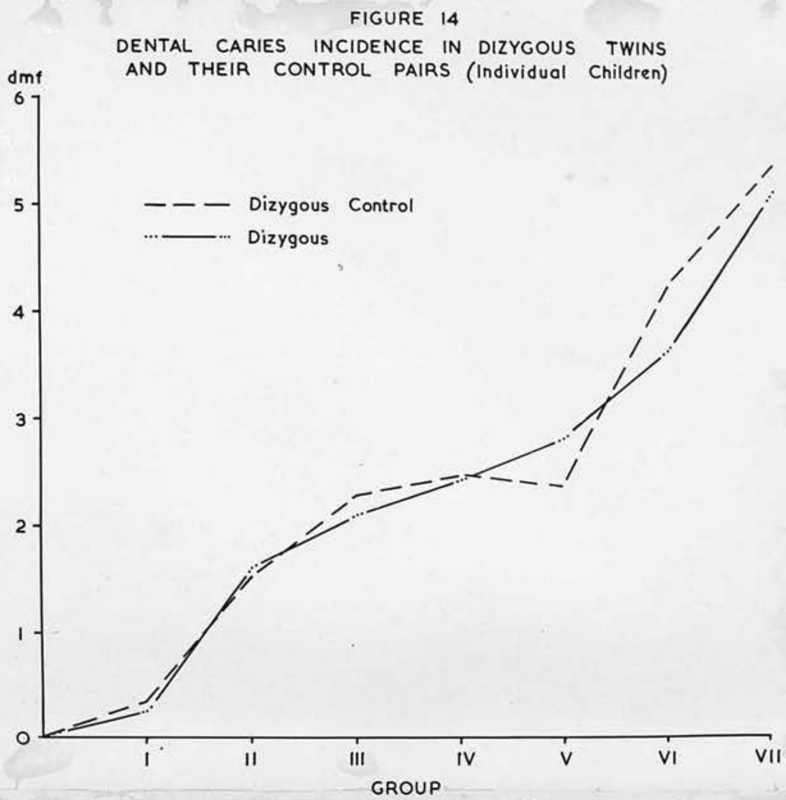


FIGURE 13
DENTAL CARIES INCIDENCE IN MONOZYGOUS TWINS AND THEIR CONTROL PAIRS (Individual Children)
dmf
6
5
4
3
2
1
0
Monozygous Control
Monozygous
I
II
III
IV
V
VI
VII
GROUP




It can be seen from the graphs above that in each case the twins more resemble their matched controls than each other in <u>total</u> dental caries experience, and no statistically significant differences were found between the twins and their control children, nor between the two control groups.

The data were now arranged so that for each twin pair A and B and for the selected control child (designated C) the state of each corresponding tooth could be compared simultaneously. For example, the lower right permanent first molar of twin A was compared with the lower right permanent first molar of twin B, and also that of A compared with that of C.

The state of each tooth was recorded as "carious" or "non-carious", using the same criteria as for the D.M.F. index.. This was done for all teeth and both groups of twins and their controls.

Results

From these data were computed the number of occasions on which corresponding teeth in twins A and B were in a "like" carious state, while those in the control pair A and C were in an "unlike" state. For example:-

| | Twin pair A | Twin pair B | Control child C |
|---|---|---|---|
| Caries (+ or -) | + | + | - |
| | - | - | + |

represents similarity in caries between the twins (AB) and concurrent dissimilarity between the control pair (AC). Also, dissimilarity in caries between the twins A and B while A and C the control pair showed similarity, was likewise recorded. For example:-

| | Twin pair A | Twin pair B | Control child C |
|---|---|---|---|
| Caries (+ or - ) | - | + | - |
| | + | - | + |

represents dissimilarity between twins A and B and similarity in caries between the control pair AC

This was done for both twin groups and all corresponding teeth were thus compared in both the permanent and deciduous dentitions.

The results of these comparisons are presented in Tables 8 and 9 following.

Table 8: Permanent Dentition

| | No. of instances in which there was similarity in corresponding teeth in twins together with dissimilarity between controls | No. of instances in which there was dissimilarity in corresponding teeth in twins together with similarity between controls |
|---|---|---|
| Monozygous twins and matched controls | | |
| Actual occurrence | 155 | 62 |
| Expected occurrence | 148 | 69 |
| Dizygous twins and matched controls | | |
| Actual occurrence | 183 | 97 |
| Expected occurrence | 190 | 90 |

$X^2 = 1.84 \qquad .20 > p > .10$

Table 9: Deciduous Dentition

| | No. of instances in which there was similarity in corresponding teeth in twins together with dissimilarity between controls | No. of instances in which there was dissimilarity in corresponding teeth in twins together with similarity between controls |
|---|---|---|
| Monozygous twins and matched controls | | |
| Actual occurrence | 137 | 52 |
| Expected occurrence | 131 | 58 |
| Dizygous twins and matched controls | | |
| Actual occurrence | 187 | 92 |
| Expected occurrence | 193 | 86 |

$X^2 = 1.584 \qquad .30 > p > .20$

From Tables 8 and 9 it can be seen that for the monozygous twins, concordance in the twins with, at the same time, discordance between the control pairs is greater than the expected value; accordingly, in the dizygous twins it is less than the expected value.

Conversely, discordance in monozygous twins with concurrent concordance in the control pairs is less than expected, while for the dizygous it is greater.

The differences between the two types of twins are small and are not statistically significant. For the permanent dentition this event could occur by chance alone, more than 1 in 10. For the deciduous teeth a similar situation obtains, but the differences are smaller and the probability of chance occurrence is more than 1 in 5.

By inspection it can be seen from Tables 8 and 9 that for both types of twins concordance between twins with discordance between control pairs is high (MZ = 155, DZ = 183), while discordance between twins with concordance between controls is low (MZ = 62, DZ = 97). When tested statistically these differences were found to be very highly significant and the probability that this could occur by chance was less than 1 in 1000 for both the permanent and deciduous dentitions.

Comparison with Previous Studies

Bachrach and Young (1927) presented data relating to the similarity of dental caries experience in twins. Much of their data are not, however, comparable with that derived from this present study, but for those data which can be compared a considerable measure of agreement is found between these two studies.

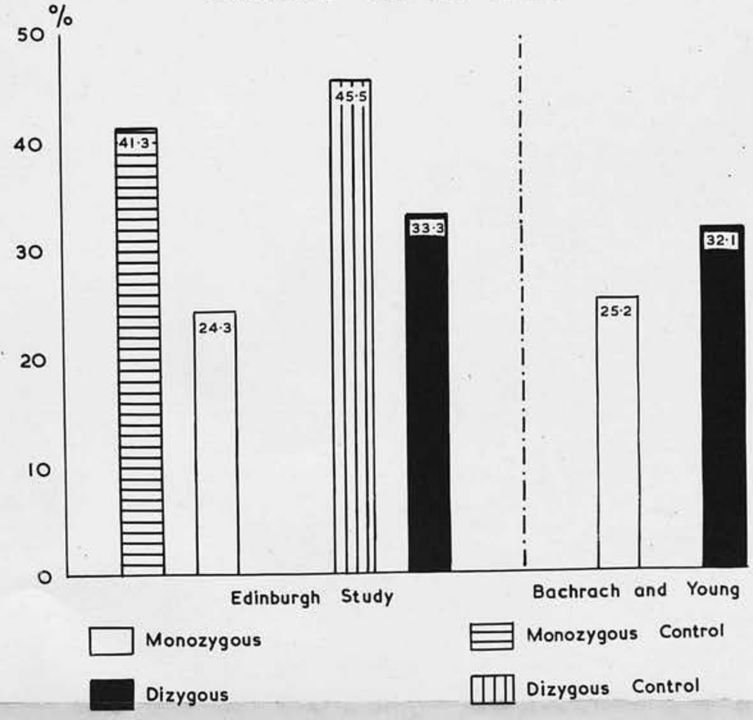
For example, they present data relating to the similarity of dental caries of the first permanent molar in twins and part of these data can be compared with equivalent data from the Edinburgh study. As previously described, there was recorded as "carious" and "non-carious" the state of each corresponding tooth in twins A and B. From the total number of tooth pairs examined it was possible, therefore, to derive the numbers of pairs in which there was concordance between the twins (i.e., both corresponding teeth carious or both non-carious) and discordance between the twins (i.e., when only one of the tooth pairs was carious). Table 10 and Figure 15 below present these data for the Edinburgh twins and for those studied by Bachrach and Young.

Table 10

The similarity of dental caries in corresponding first permanent molars in pairs of twins

| | Concordance | Discordance |
|---|---|---|
| Bachrach and Young | % tooth pairs | % tooth pairs |
| Monozygous | 74.8 | 25.2 |
| Dizygous | 67.9 | 32.1 |
| Edinburgh Study | | |
| Monozygous | 75.7 | 24.3 |
| Monozygous Control | 58.7 | 41.3 |
| Dizygous | 66.7 | 33.3 |
| Dizygous Control | 54.5 | 45.5 |

FIGURE 15
FIRST PERMANENT MOLAR
Proportion of Corresponding Tooth Pairs in which only one of the Corresponding Teeth was Carious



Dahlberg and Dahlberg (1942), in an investigation of dental caries in monozygous and dizygous twins, found differences between the two types of twins which were not, however, statistically significant. None the less, they calculated comparable values of genetic and environmental factors and from these it was concluded that inherited factors were at least half as important as environmental factors, and at most, of equal importance. The use of the control groups in this present study to provide a standard against which the respective twin groups might be measured and compared, suggested a possible method by which an approximation for genetic and environmental factors might be made and compared with those calculated by Dahlberg and Dahlberg.

If it can be assumed that the two groups of unrelated control pairs are representative samples of Edinburgh children and that they differ from each other only in respect of those features which governed their selection, that is, age, sex and number of teeth erupted, then the relationship between the twins and their respective control groups provides a basis for comparison of the two twin groups, the control groups providing the "yardstick" against which the twins may be measured. Figure 15 (p. 87) shows graphically the general relationship for the first permanent molar.

Differences in discordance between monozygous twins and their control pairs may be regarded as due to

(a) the common environment of the twins, compared with the dissimilar environment of the control pairs;

and (b) the identical hereditary constitutions of the twins compared with the dissimilar heredity of the controls.

However, differences in discordance between dizygous twins and their control pairs can be regarded as due only to (a), the shared environment of the twins compared with the dissimilar environment of the control pairs.

From the data given in Table 10 (p. 87), the differences described above may be given numerical values. The differences in discordance between monozygous twins and their control pairs of dental caries experience in corresponding first permanent molars is 17 per cent (41.3 - 24.3). That between dizygous twins and their control pairs is 12.2 per cent (45.5 - 33.3).

Environmental and genetic differences together, then, constitute 17 per cent and environmental differences alone 12.2 per cent. Therefore the part contributed by genetic differences alone would seem to be 4.8 per cent (17.0 - 12.2). The ratio then of genetic to environmental influence would be in this instance 4.8 : 12.2 or 1 : 2.5.

It is of interest to observe that Dahlberg and Dahlberg (1942) concluded from a mathematical analysis of their twin data that the comparative values of genetic and environmental factors were in the ratio of 1 : 2 respectively at the least.

When the data for the deciduous dentition and the total permanent teeth were similarly examined, the following results were obtained (see Table 11 below).

Table 11

Proportion of tooth pairs in which one only of the corresponding teeth was carious.

| | All Permanent Teeth | Deciduous Teeth |
|---|---|---|
| | % | % |
| Monozygous | 9.7 | 38.9 |
| Monozygous Control | 18.0. | 58.7 |
| Dizygous | 12.5 | 43.3 |
| Dizygous Control | 17.3 | 58.2 |

For the deciduous teeth, the proportion of the total discordance contributed by genetic differences alone was found to be 4.9 per cent, while for all the permanent teeth combined the proportion due to genetic differences amounted to 3.5 per cent.

The ratio of genetic to environmental influence was found to be 1 : 3 for the deciduous teeth and 1 : 1.4 for the permanent teeth.

## Discussion

The present study was based upon the knowledge that monozygous twins have an identical hereditary constitution, while dizygous twins each possess their own distinctive genotype and are no more alike than ordinary siblings, except that they were born at the same time. Furthermore, it has been assumed in this study that the post-natal environment shared by the twins is equal whether they are monozygous or dizygous.

This being so, it could be expected that if constitutional factors do in fact exert any influence in determining susceptibility to dental caries, a comparison of the similarity of dental caries experience in monozygous and dizygous twins should show monozygous twins to be more alike than dizygous.

However, the wealth of evidence presented in the literature relating to dental caries provides clear indication that environmental factors, especially diet, play a major part in the aetiology of this disease, and therefore, if any genetic influence existed, it would seem likely to be small. A review of the relevant literature lent further support to this view. For this reason, then, it seemed doubly important that in any comparison of twins all possible sources of bias in the two samples should be adequately controlled, in order that such differences as might exist could be clearly recognised and not obscured by the effects of other variables. Also, this need was all the greater in a twin study, where of necessity the number of twins available for examination was limited.

In the two studies of twins which have been reviewed, the two types of twins have been directly compared with each other and, although the writers found no significant differences in the ages of the twins, small differences in age and sex structure could conceivably introduce bias, especially in small samples. This was avoided in the present study by the use of matched control children, alike in age, sex and approximately an equal stage of dental development and therefore in these respects comparable with the twins whom they matched.

The results of this study show that between both types of twins and their respective controls the differences in similarity of caries experience were very highly significant, the twins showing high concordance and low discordance in dental caries, while the controls showed low concordance and high discordance. However, the data indicated that, while the monozygous twins differed from their control pairs to a greater extent than did the dizygous from their controls, the probability that this could be a chance occurrence was greater than 1 in 10 for the permanent dentition and greater than 1 in 5 for the deciduous teeth. However, the highly significant difference between all twins and the control pairs provides convincing evidence that the shared environment of the twins resulted in a greater similarity in their dental caries experience, whilst the dissimilar environment of the unrelated pairs resulted in a considerable difference in dental caries between the pair members.

From this it can be concluded that environmental conditions constitute a major factor in the aetiology of this disease.

The study made by Bachrach and Young (1927) is of interest in comparison with the present study, for in spite of differences in evaluating dental caries experience, their results and those of this study show a considerable measure of agreement.

In contrast to this present study, where presence/absence of dental caries only is the criterion, Bachrach and Young, in their analysis of corresponding first molar pairs, compared not only number of pairs showing presence or absence of dental caries, but also attempted to compare degree of caries attack. The estimation of degree of dental caries is difficult and uncertain, with the result that the degree of accuracy is subject to considerable variation. Furthermore, to demand correspondence in degree of caries in monozygous twins is to apply too strict a test of similarity, especially by a method so liable to error in estimation.

Since the progress and extent of the carious lesion is to a considerable extent a function of time, a comparison of degree of caries between corresponding teeth would seem to demand of any possible genetic influences that they should operate in both twins at almost the same point in time. This seems a very stringent demand for a disease in which environment plays if anything a larger part than genetics. Even with a clear genetic factor, it is still to be expected that its expression would vary with time in response to the environmental influences which are amplifying its genetic basis.

Dahlberg and Dahlberg (1942), in a study of monozygous and dizygous twins, showed that discordance in dental caries between corresponding teeth was less in monozygous than in like-sex dizygous twins. This is in agreement with the findings of Bachrach and Young, and of those for the Edinburgh study. The similarity between Dahlberg and Dahlberg's findings and those of this present investigation are of interest. The percentage for all permanent teeth combined in which only one of a pair of corresponding teeth in twins was carious is given below for Dahlberg and Dahlberg's data and for the present study.

| All permanent teeth | Dahlberg and Dahlberg | Edinburgh Study |
|---|---|---|
| | % | % |
| Monozygous twins | 10.7 | 9.7 |
| Like-sex Dizygous twins | 14.6 | 12.5 |

Although Dahlberg and Dahlberg found that the difference they observed between monozygous and like-sex dizygous twins was not <u>statistically</u> significant, in a further analysis of their data they calculated by mathematical formulae comparative values of genetic and environmental factors and from these concluded that the ratio of genetic to environmental influences in the incidence of dental caries was at least 1 : 2 and that therefore the genetic factor appeared to be by no means negligible.

In order to compare the Edinburgh data with Dahlberg and Dahlberg's findings, an attempt has been made to give a numerical value to the various components of the difference between monozygous and dizygous twins in terms of genetic and environmental differences.

The results obtained are in agreement with those of Dahlberg and Dahlberg and it is therefore of interest to consider the further implications of Dahlberg and Dahlberg's conclusions in the light of a similar treatment of the Edinburgh data.

The varying ratio of genetic to environmental contribution for the three classes of teeth examined are of some interest. The environmental factor would appear to be related to duration of exposure, and since this disease is cumulative in its total effect, increase in age will result in a corresponding increase in accumulated environmental effects. If this is so, the result to be expected would be in the direction of a relative decrease in genetic contribution with increase in age, compared with the environmental effects.

In the three groups of teeth examined here the deciduous teeth have had a longer duration in the mouth than the first permanent molar since the approximate ages of those children from whom the data were derived are, for the deciduous dentition 6.5 years and, for the permanent teeth, nine years. The deciduous dentition is completed with the eruption of the second deciduous molar at approximately 2 to 2½ years of age and therefore most of the deciduous molar and canine teeth have been exposed in the mouth for over four years. In regard to the first permanent molar, however, this is the first permanent tooth to erupt and by nine years of age (the mean age of the twin and control groups) has been exposed to the oral environment for about three years. Therefore for the total permanent dentition, the average duration in the mouth for all the permanent teeth must be even less.

Goldberg (1930), from a study of 42 pairs of monozygous twins, concluded that the influence of heredity upon dental caries incidence was only indirect, by its influence upon tooth morphology, especially the formation of pits and fissures. He observed that caries of smooth surfaces was very haphazard in distribution between twins, while that occurring in pits and fissures showed greater uniformity. He also observed evidence of reversal of asymmetry in pits and fissure formation - clearly suggesting an inherited pattern.

During the collection of the data for this present study, the striking similarity of tooth morphology in monozygous twins was observed, and was in contrast to the generally greater variation in tooth morphology seen in obviously dizygous pairs. Furthermore, Bachrach and Young found that in monozygous twins the proportion of pairs in which hypoplasia was present in the teeth of both twins was significantly higher than in dizygous pairs. Since such macroscopic faults in tooth structure can be shown to have a genetic basis, it is not unlikely that microscopic faults in tooth structure may equally be genetic in origin.

It is recognised that structural faults in teeth do not inevitably become the site of carious attack but, given suitable environmental conditions in the mouth, such faults provide at least a predisposing factor to subsequent caries.

Reid and Grainger (1955) have shown that caries of smooth as compared to pitted surfaces may differ in aetiology and that dental caries of smooth surfaces seems to reflect environmental conditions in the mouth. They also observed that the presence of a deep pit or fissure seemed to result in a cavity developing soon after eruption of the tooth. From this it would seem that caries of pits and fissures is more dependent upon developmental factors, while caries affecting smooth surfaces of the tooth is more dependent upon the oral environment.

In this way then, the differing ratios of genetic to environmental influences in dental caries, as calculated for the deciduous and permanent teeth, provide an explanation that is consistent with the evidence derived from this and other studies.

The relatively high genetic influence calculated for the total permanent teeth may be explained by the fact that at an average age of nine years (the average age of the twins in this present study), a very large proportion of the teeth are recently erupted and pit and fissure caries predominate over smooth surface caries in the younger age groups, due to the observed fact that pits and fissures are attacked early after eruption, while smooth surface caries requires a longer period of oral exposure.

In the case of the deciduous teeth, however, the longer duration of these in the mouth may have resulted in the accumulation of environmental effects in the form of smooth surface caries, while the bulk of pit and fissure lesions have already developed at an earlier age and no increase in this number is now likely.

The observed increased effect of environment with time is consistent with the presence of a morphological characteristic which predisposes, but can be overlain by environmental effects with time. It is therefore suggested that any genetic influence in the incidence of dental caries would seem most likely to be developmental in effect and influence susceptibility to caries indirectly through its effect on pit and fissure formation.

The comparison of this study of twins with the two earlier studies shows a remarkable degree of agreement in those aspects which could be compared. In terms of numerical values the likeness is noteworthy, and furthermore, in all three studies the similarity in caries experience in monozygous twins was greater than that in dizygous twins.

While in each of these three studies by themselves the differences between the two types of twins in dental caries experience werenot of such a magnitude as to be statistically significant, taken together, however, they provide consistent findings which can only be overturned by an even larger inquiry than these and therefore seem to warrant the conclusion that the greater similarity in dental caries experience between monozygous as compared with dizygous twins is in fact real and not due to chance occurrence and hence, that a genetic influence exists in the aetiology of dental caries.

Nevertheless, the use of matched control pairs provides significant evidence to show that environment plays the major part in determining susceptibility to dental caries. This latter finding, derived from the differences observed between twins with their common environment and unrelated pairs of children, is remarkable when viewed against the background of the relatively homogeneous environment of modern urban civilisation. It suggests either that greater differences in individual environment exist than might be expected, or that susceptibility to dental caries is very sensitive to relatively minor environmental differences.

# CHAPTER V

## The Influence of Social Class Differences on the Incidence of Dental Caries

The effects of social and economic conditions on the health of the community are well recognised and documented. For example, the rate of mortality in the first year of life is recognised to be a sensitive index of the effects of various social factors since those which predispose to disease weigh heavily on the infant. The Registrar General publishes annually data relating to infant mortality according to the occupation of the father, showing that there is a steady increase in mortality between Social Class I (the professional class) and Social Class V (the unskilled labourer). The social conditions associated with these differences in infant mortality are generally accepted to be poverty, size of family, standards of education of the mother influencing standards of maternal care and, of those possible aetiological factors which arise from these social conditions, that of nutrition has ranked high in importance. The dramatic reduction in infant mortality rates during the last war are often ascribed to improved standards of nutrition and full employment. In spite of these improvements, however, differences in mortality rates of infants continue to exist between differing social classes and the relative disparity between them remains. Table 11 shows the Infant Mortality Rates by Social Class for Scotland for the years 1939, 1946 and 1956 (see p. 100).

The Annual Reports of the National Food Survey Committee on domestic food consumption and expenditure for 1952 and 1953 indicated that social class differences in food consumption existed and that they varied considerably for different foods. It was also shown that the nutrient value of the diets of the

Table 12

Infant Mortality Rates by Social Class - Scotland

(Registrar-General for Scotland Annual Reports)

| Social Class | 1939† | 1946 | 1954 |
|---|---|---|---|
| I | 33.1 | 22.2 | 15.7 |
| II | 39.6 | 37.8 | 22.1 |
| III | 68.3 | 51.3 | 30.9 |
| IV | 67.8 | 60.3 | 31.6 |
| V | 84.2 | 73.0 | 42.0 |
| All Classes | 68.5 | 53.8 | 31.0 |

† From 1943 Report

different social groups declined from Social Class A (where the gross weekly income of the head of the household was over £15) to Social Class C (where the gross weekly income was under £6). The social class differences in the nutrient value of the diets was not, however, considered of nutritional importance, but it was shown that size of family exerted a much greater influence. Analysis of nutrient content and energy value demonstrated that these were satisfactory for households up to and including two children, but that for those with three or more children, the diet fell below the recommended levels for protein, calcium, iron and riboflavin.

Although the differences in nutrient value of the diet between the social groups were not nécessarily of nutritional importance, it is possible that the difference in the types and amounts of food might exert some influence upon suscepti-bility to dental caries. For example, the consumption per person per week of sugar and preserves, biscuits and 'other' cereals is higher in social group A than in the other three social groups.

The knowledge that diet and nutrition are associated with susceptibility to dental caries suggests that differences in dental caries prevalence might be found at different social levels.

In the Report of the Interdepartmental Committee on Physical Deterioration (1904), the evidence of one of the witnesses examined by the Committee on the state of the teeth of the British people was to the effect that dental caries incidence was highest among children attending the better class schools and the higher the social class, the higher the prevalence of dental caries. It was also stated that, on examination of two schools in Edinburgh, the rate of defective permanent teeth per 1,000 children was found to be 158.2 in a school for children of well-to-do working people, and 273.9 in that for the children of professional men and merchants.

Mitchell (1933), in a study of Porto Rican children aged 10 years, concluded that children with a better socio-economic status appeared to have a greater susceptibility to dental caries than children of poorer socio-economic groups. Dental caries was measured by the extent of tooth destruction of the first permanent molar in terms of filled, unfilled and extracted teeth, and the dental caries scores were derived from a degree index. The data indicated that urban children had a greater susceptibility to dental caries than rural children and also that when rural children were grouped as "peasant" and "non-peasant", the "Peasant" group (described as a very under-privileged social class) showed a lower average dental caries experience than the "non-peasant".

The relationship of three socio-economic factors with dental caries was examined for urban and non-peasant rural children, and for both groups it was observed that "economic rating" showed, with only one exception, a low but consistently negative correlation. The "number of persons per room" was consistently negative, while on the other hand the "number of rooms in the house" was with one exception, consistently positive. The author considered that, although the correlations between these three social indices and dental caries were low, they were so consistent with other data which suggested a higher prevalence of dental caries in the "better off" social groups, that he considered they were probably significant.

In this country, Wilkins (1941) reported the finding of 6 per cent of five-year old Birmingham children in elementary schools with sound teeth, compared with 70 per cent among children of the same age in private schools. In the poorer elementary schools the average number of decayed, missing, filled or severely hypoplastic teeth was 6.9 per child, while in private school children only 1.16 teeth per child were found.

However, Klein and Palmer (1942), from data derived from a dental examination of 2,595 New York City school children, aged 11 to 19 years in private and non-fee-paying schools, concluded that socio-economic factors did not appear to influence susceptibility to dental caries.

In the United States, Hyde (1944) studied the dental condition of males called for examination prior to enlistment in th e United States Army during 1942-43. In a group of nearly 4,000 men, most of whom were in the age group 18-20 years, he observed that those from the highest socio-economic level showed a rate of 17 D.M.F. teeth, while those from the lowest level showed a rate of only 14 D.M.F. teeth.

Three explanations were offered for this difference:

(a) The possible prophylactic filling of non-carious fissures in the higher socio-economic groups.

(b) The lower socio-economic groups were shown to contain a higher proportion of foreign born individuals, some of whom belonged to races with a lower susceptibility to caries than the average American.

(c) The possibility that the supposedly superior nutrition of the higher social groups may be in some way responsible for their higher dental caries experience.

Coumoulos and Mellanby (1947) reported the results of a survey of the dental condition of the deciduous teeth of five-year old children in London. Their results indicate that those children who attended fee-paying private schools had a lower incidence of dental caries than comparable children attending L.C.C. schools, but that when compared to five-year old children living in institutions, both the private and L.C.C. school children showed a considerably higher incidence of caries.

They also reported that tooth structure, as defined by examination of the tooth surfaces in the mouth, was superior in those children from private schools and worst in those children living in institutions. It is interesting, then, to find that those children with the worse tooth structure, i.e., the institutional children, have the lower incidence of dental caries, while those with the best structure have a higher incidence.

However, when the three groups of children were analysed relationship was found between tooth structure and dental caries incidence. Within any one group, those who were assessed as having poor structure had a higher incidence of caries than those whose tooth structure was considered good. These findings indicate that, while good structure of surface enamel is associated with a lessened incidence of dental caries, clearly this advantage would seem capable of being overwhelmed by certain environmental factors.

Savara and Suher (1955) made a study of dental caries in children of one to six years of age and investigated the possible influence of socio-economic factors, food habits and tooth brushing upon the incidence of dental caries. Information regarding the socio-economic status of the parents was obtained by means of personal interview of the parents in the home, using a standardised questionnaire, and the parents of 279 children were so interviewed. Information was also obtained about the food and oral hygiene habits of the children at the home visit.

It was found that neither income nor type of employment were related to the dental caries experience of the child, but that the number of years of father's education was strongly associated with caries in the child, the correlation being negative. The number of years of mother's education was also negatively correlated with the child's caries experience. Standards of parental education were also found to be associated with the number of times per day the child brushed his teeth, a positive correlation being obtained.

Finally, no association was found between income of parent and food habits of the child.

The literature reviewed, although not unanimous, clearly suggests that differences in dental caries experience are found between children at different social levels.

In order to investigate further the possibility of differences in the incidence of dental caries between socially distinct groups, a comparison was made between children who were attending fee-paying schools as day pupils and those who were attending non-fee-paying schools.

Methods

As described in Chapter I, part of the total sample of Edinburgh children examined was derived from fee-paying schools, the fees for which are considerable. The children from these schools can be regarded as representative of Social Class I as defined by the Registrar General, namely, the professional classes. The non-fee-paying children all attended Education Authority primary or secondary schools and were regarded as representative of Social Classes III, IV and V.

A preliminary examination of the data revealed consistant differences in dental caries between fee-paying and non-fee-paying children. Since the numbers of children in the fee-paying group were relatively small compared with those in the non-fee-paying group, it was evident that any attempt to compare these two classes of children according to dental or chronological age could only result in such small numbers of fee-paying children in each age group that no reliable comparison would be possible.

It was therefore decided to form all fee-paying children into one group and to select for each fee-paying child two children of the same sex, age and number of teeth erupted from the total sample of non-fee-paying children. In this manner a group of children who attended non-fee-paying schools was obtained, which had the same structure in terms of age, sex and number of teeth erupted as the fee-paying group but of twice the size. These non-fee-paying children were randomly selected from their appropriate age group of the total sample.

It was now possible to compare the fee-paying with the non-fee-paying children directly, with reasonable assurance that any differences observed in dental caries incidence between them could not be due to inequalities in age or dental development. Table XII in the Appendix shows the comparison between the groups and indicates the magnitude of the differences between them in terms of both age and number of teeth erupted.

Results

Deciduous Teeth

The average number of decayed, missing and filled deciduous molars and canine teeth per child was calculated for both social groups and for the sexes separately, and these data are given in Table 13 below.

Table 13

Mean d.m.f. deciduous molar and canine teeth of children aged 5 - 8 years in fee-paying and non-fee-paying schools, both groups matched in respect of age

| | Boys | | Girls | |
|---|---|---|---|---|
| | Fee paying | Non-fee paying | Fee paying | Non-fee paying |
| Number of children | 36 | 72 | 43 | 86 |
| Mean d.m.f. teeth | 3.25 | 6.07 | 4.56 | 6.41 |
| Standard error of mean | 0.53 | 0.41 | 0.55 | 0.38 |

It can be seen from Table 13 that the incidence of dental caries of deciduous molar and canine teeth is appreciably higher among children attending the non-fee-paying schools than among those children who attend the fee-paying schools included in this survey. The difference between the two groups of boys is greater than that between the girls and in both instances the mean differences are statistically significant. For the differences between boys $t = 4.208$ ($p < .001$), and for girls $t = 2.767$ ($p < .01$).

Permanent Teeth

The number of children in Group VII (25-28 teeth erupted) was adequate to permit comparison and so the data for this group are presented as well as those for all groups I - VIII combined. Table 14 shows the difference in the average number of D.M.F. teeth per child between children from fee-paying and non-fee-paying schools.

Table 14

Decayed, Missing and Filled Permanent Teeth

| Group | Fee-paying | | | Non-fee-paying | | |
|---|---|---|---|---|---|---|
| | No. of Children | Mean D.M.F. Teeth per Child | Standard Error | No. of Children | Mean D.M.F. Teeth per Child | Standard Error |
| BOYS | | | | | | |
| VII | 87 | 6.03 | 0.40 | 174 | 5.33 | 0.27 |
| All Groups | 168 | 4.64 | 0.30 | 336 | 3.98 | 0.20 |
| GIRLS | | | | | | |
| VII | 97 | 7.44 | 0.43 | 194 | 6.52 | 0.28 |
| All Groups | 169 | 5.49 | 0.33 | 338 | 4.86 | 0.22 |

In contrast to the deciduous teeth, the differences between children attending fee-paying compared with non-fee-paying schools are reversed and the fee-paying children of both sexes now show a higher average number of D.M.F. teeth per child than the non-fee-paying children. However, the differencesin average D.M.F. teeth per child between fee-paying and non-fee-paying children were in no instance statistically significant. This applied to both Group VII and "All groups combined".

Table 15 shows the difference between fee-paying and non-fee-paying children when the dental caries experience of the two social groups is expressed as the number of D.M.F. teeth per 100 teeth erupted.

Table 15

Decayed, Missing and Filled Permanent Teeth per 100 teeth erupted

| | Fee-paying | Non-fee-paying | p |
|---|---|---|---|
| | % | % | |
| All Groups | | | |
| Boys | 21.46 | 13.36 | $< .001$ |
| Girls | 24.66 | 22.23 | $< .01$ |
| Group VII | | | |
| Boys | 22.03 | 19.43 | $< .02$ |
| Girls | 27.12 | 23.75 | $< .01$ |

It can be seen from Table 15 that there is a significant difference between the two social groups in the proportion of the total number of teeth attacked by caries.

Distribution of dental caries in permanent teeth according to tooth surface

To determine whether differences existed between fee-paying and non-fee-paying children in respect of the tooth surfaces involved, decayed and filled surfaces were tabulated for each morphological class of tooth.

For convenience of presentation, tooth surfaces have been classified as follows:-

Approximal  Mesial and distal surfaces combined

Occlusal

Other Surfaces  Labial or buccal and lingual surfaces combined.

In addition, when two or more surfaces were attacked, they were included in a separate category.

Tables 16 and 17, following, present the contribution made by extracted teeth and by decayed and filled teeth according to tooth surface involved, to the total dental caries experience of each morphological class of tooth except incisors and canines. The values are expressed as a percentage of the total number of decayed, missing or filled teeth.

MAXILLA

Incisors

It will be seen from Tables 16 and 17 that in boys and girls the major difference between the fee-paying and non-fee-paying groups is in the percentage of teeth missing due to dental caries (teeth lost due to trauma having been excluded).

Premolars and Molars

The only consistent difference between the two groups in regard to their dental caries experience of premolar and molar teeth lies in

(a) the higher percentage of occlusal caries in the non-fee-paying group, and

(b) the higher percentage of "two or more" surfaces involved in the fee-paying group.

This latter difference is to some extent due to the

Table 16

Proportion of total D.M.F. contributed by decayed and filled approximal, occlusal and other surfaces of certain morphological classes of teeth in fee-paying and non-fee-paying children

BOYS

| Tooth | | Total D.M.F. Teeth | Decayed and Filled Surfaces | | | | Missing Teeth |
|---|---|---|---|---|---|---|---|
| | | | Approximal | Occlusal | Other | Two or more | |
| | | % | % | % | % | % | % |
| **Maxilla** | | | | | | | |
| $I_1$ | FP | 100 | 62.3 | - | 6.6 | 31.2 | - |
| | NFP | " | 76.4 | - | 4.4 | 10.4 | 8.8 |
| $I_2$ | FP | " | 50.0 | - | 48.0 | 2.0 | - |
| | NFP | " | 46.7 | - | 34.6 | 7.9 | 10.9 |
| C | FP | " | 100.0 | - | - | - | - |
| | NFP | " | 30.0 | - | 40.0 | - | 30.0 |
| $PM_1$ | FP | " | 35.9 | 10.3 | 23.1 | 25.6 | 5.1 |
| | NFP | " | 19.4 | 59.2 | 2.0 | 14.3 | 5.1 |
| $PM_2$ | FP | " | 28.9 | 26.7 | - | 35.6 | 8.9 |
| | NFP | " | 33.9 | 34.9 | 0.9 | 13.8 | 16.5 |
| $M_1$ | FP | " | 3.1 | 54.6 | 0.7 | 28.2 | 13.4 |
| | NFP | " | 1.5 | 72.3 | 1.3 | 16.7 | 8.2 |
| $M_2$ | FP | " | 1.4 | 81.3 | 1.4 | 15.8 | - |
| | NFP | " | 0.5 | 93.6 | 2.4 | 2.7 | 0.8 |
| **Mandible** | | | | | | | |
| $PM_1$ | FP | " | 50.0 | 16.7 | 8.3 | 8.3 | 16.7 |
| | NFP | " | 23.1 | 30.8 | 7.7 | 11.5 | 26.9 |
| $PM_2$ | FP | " | 33.3 | 29.6 | - | 22.2 | 14.8 |
| | NFP | " | 13.8 | 36.3 | 6.3 | 8.8 | 35.0 |
| $M_1$ | FP | " | 5.4 | 38.1 | 4.4 | 33.3 | 18.7 |
| | NFP | " | 2.3 | 53.2 | 3.4 | 22.9 | 16.3 |
| $M_2$ | FP | " | 0.8 | 65.4 | 5.4 | 26.9 | 1.5 |
| | NFP | " | 0.3 | 75.7 | 9.8 | 9.8 | 4.5 |

FP - Fee-paying NFP - Non-fee-paying

Table 17

Proportion of total D.M.F. contributed by decayed and filled approximal, occlusal and other surfaces of certain morphological classes of teeth in fee-paying and non-fee-paying children

GIRLS

| Tooth | | Total D.M.F. Teeth | Decayed and Filled Surfaces | | | | Missing Teeth |
|---|---|---|---|---|---|---|---|
| | | | Approximal | Occlusal | Other | Two or more | |
| | | % | % | % | % | % | % |
| **Maxilla** | | | | | | | |
| $I_1$ | FP | 100 | 65.0 | - | 6.0 | 27.0 | 2.0 |
| | NFP | " | 78.6 | - | 3.2 | 15.7 | 2.5 |
| $I_2$ | FP | " | 60.7 | - | 27.0 | 11.2 | 1.1 |
| | NFP | " | 61.2 | - | 23.7 | 9.4 | 5.8 |
| C | FP | " | 88.2 | - | 5.9 | 5.9 | - |
| | NFP | " | 84.2 | - | 5.3 | 5.3 | 5.3 |
| $PM_1$ | FP | " | 17.6 | 41.9 | - | 35.1 | 5.4 |
| | NFP | " | 18.5 | 52.5 | 1.2 | 17.3 | 10.5 |
| $PM_2$ | FP | " | 13.0 | 28.6 | - | 46.8 | 11.7 |
| | NFP | " | 25.8 | 46.7 | - | 14.4 | 13.2 |
| $M_1$ | FP | " | 2.7 | 50.1 | 0.5 | 27.5 | 19.1 |
| | NFP | " | 1.3 | 68.2 | 1.3 | 17.2 | 12.0 |
| $M_2$ | FP | " | 0.5 | 77.4 | 1.9 | 20.3 | - |
| | NFP | " | - | 94.6 | 0.7 | 4.7 | - |
| **Mandible** | | | | | | | |
| $PM_1$ | FP | " | 26.7 | 20.0 | 6.7 | 26.7 | 20.0 |
| | NFP | " | 17.7 | 64.7 | 5.9 | 11.8 | - |
| $PM_2$ | FP | " | 28.6 | 28.6 | 3.2 | 25.4 | 14.3 |
| | NFP | " | 22.4 | 43.9 | 3.7 | 8.4 | 21.5 |
| $M_1$ | FP | " | 3.3 | 35.9 | 2.2 | 36.2 | 22.4 |
| | NFP | " | 1.3 | 51.6 | 4.2 | 20.8 | 22.1 |
| $M_2$ | FP | " | 0.9 | 73.0 | 2.6 | 22.3 | 1.3 |
| | NFP | " | 0.2 | 81.3 | 3.9 | 10.5 | 4.2 |

greater amount of conservative dental treatment observed in the fee-paying group, and consists in part of fillings which may have been extended to another surface for operative reasons alone.

MANDIBLE

The mandibular incisors and canines have been excluded from the Table since the incidence of dental caries in these teeth is so low.

Premolars and Molars

The incidence of dental caries of the first premolar is so low that no reliable conclusions can be made.

For the remaining teeth, however, it will be seen that caries of the occlusal surface is consistently higher in the non-fee-paying children.

The percentage differences in occlusal lesions between fee-paying and non-fee-paying children is statistically significant in respect of all molar teeth, maxillary and mandibular in both sexes. For girls the difference between fee-paying and non-fee-paying, in respect of occlusal lesions in the premolar teeth, are statistically significant, with one exception. Between the two groups of boys, however, the differences in occlusal lesions in premolars are generally not statistically significant.

Table 18 presents the percentage of maxillary incisor, premolar and molar teeth, and also mandibular molar teeth, which are non-carious for both the fee-paying and non-fee-paying groups. The maxillary canine teeth and all mandibular teeth except the first and second permanent molars are excluded from this table, since the percentage caries-free was so high that there was manifestly no important difference between the two groups.

It can be seen from Table 18 that the fee-paying children have a considerably smaller percentage of teeth non-carious as compared with the non-fee-paying children. This difference is seen in both sexes.

The differences in the percentages of non-carious permanent teeth between the two groups of socially distinct children are statistically highly significant.

Table 18

Percentage of teeth non-carious in children attending fee-paying and non-fee-paying schools

| Tooth | Boys | | Girls | |
|---|---|---|---|---|
| | Fee-paying | Non-Fee-paying | Fee-paying | Non-Fee-paying |
| **Maxilla** | | | | |
| $I_1$ | 84.7 | 93.6 | 78.6 | 90.8 |
| $I_2$ | 86.3 | 93.1 | 79.9 | 91.8 |
| $PM_1$ | 87.1 | 94.2 | 80.2 | 91.7 |
| $PM_2$ | 84.7 | 91.9 | 77.9 | 89.6 |
| $M_1$ | 29.4 | 41.7 | 22.5 | 36.0 |
| $M_2$ | 46.9 | 61.8 | 39.4 | 56.7 |
| **Mandible** | | | | |
| $M_1$ | 27.7 | 47.1 | 23.6 | 36.8 |
| $M_2$ | 53.6 | 65.0 | 35.1 | 58.7 |

Standards of Oral Hygiene

For every child examined in this study, with few exceptions, the child's standard of oral hygiene was assessed as good, fair, or neglected. Table 19 below presents the results for children in fee-paying and non-fee-paying schools.

Table 19

The number and percentage of children in fee-paying and non-fee-paying schools whose standards of oral hygiene are classed as Good, Fair and Neglected

| | Oral Hygiene | | |
|---|---|---|---|
| | Good | Fair | Neglected |
| **Boys** | | | |
| Fee-paying | 100 (66%) | 54 (32%) | 4 (2%) |
| Non-fee-paying | 144 (43%) | 139 (41%) | 52 (16%) |
| **Girls** | | | |
| Fee-paying | 134 (80%) | 32 (19%) | 2 (1%) |
| Non-fee-paying | 197 (58%) | 117 (35%) | 24 (7%) |

It can be seen that differences in the standards of hygiene between fee-paying and non-fee-paying children of both sexes are considerable and are in the direction that would be expected.

In Table 20 following, the results are tabulated for non-fee-paying children of both sexes together with the mean number of decayed, missing and filled teeth, for tooth groups I to VII.

Table 20

Assessment of oral hygiene standards and the mean number of decayed, missing and filled teeth per child in 3,261 Non-fee-paying children.

| | Boys (1,584) | | | Girls (1,677) | | |
|---|---|---|---|---|---|---|
| Oral Hygiene | Good | Fair | Neglected | Good | Fair | Neglected |
| | D.M.F. | D.M.F. | D.M.F. | D.M.F. | D.M.F. | D.M.F. |
| Group I<br>Mean D.M.F. | 0.34 | 0.17 | 0.17 | 0.19 | 0.37 | 0.0 |
| Group II<br>Mean D.M.F. | 0.87 | 1.24 | 2.25 | 0.99 | 0.97 | 2.00 |
| Group III<br>Mean D.M.F. | 1.52 | 2.10 | 2.22 | 2.00 | 2.47 | 3.22 |
| Group IV<br>Mean D.M.F. | 2.12 | 2.15 | 3.08 | 2.34 | 2.64 | 3.61 |
| Group V<br>Mean D.M.F. | 2.94 | 2.73 | 3.32 | 2.85 | 3.04 | 5.13 |
| Group VI<br>Mean D.M.F. | 2.89 | 3.72 | 3.82 | 3.24 | 4.29 | 4.23 |
| Group VII<br>Mean D.M.F. | 4.82 | 5.52 | 5.92 | 5.80 | 6.02 | 7.57 |

It will be seen that, in general, the mean number of decayed, missing and filled teeth, is considerably less for children of both sexes with "good" oral hygiene than it is for those children with only "fair" or "neglected" hygiene.

## Discussion

The results presented show distinct and significant differences in the incidence of dental caries between children belonging to two contrasting social groups. These differences are of special interest because it was found that their direction was reversed between the deciduous and permanent teeth, namely that fee-paying children showed a lower incidence of dental caries of the deciduous teeth, but a higher incidence of caries of the permanent teeth.

The finding that the children with the better socio-economic environment had a lower incidence of dental caries of their deciduous teeth is in agreement with the findings for disease in general, that there is an upward gradient in incidence from Social Class I to Social Class V. This is well illustrated by the disparity found in infant mortality rates between the social classes, where for Social Class I the rate is about half that found in Social Class V. It is also of interest that standards of nutrition of the expectant mother are generally regarded as exerting an important influence upon the physical status of the child at birth. Baird (1945) discusses the fact that still-birth and neo-natal rates appear to be controlled by social conditions operating through the mother and suggested that the dramatic reduction in these rates in Britain during the war appeared to be due to some factor on a national scale, probably improved nutrition among mothers in the lower social groups.

Mellanby and Coumoulos (1944), discussing the improvement in the teeth of five year old London children between 1929 and 1943, suggested that the reduced incidence of caries observed was directly associated with improvement in structure of these teeth and, further, that this was in turn related to improvements of maternal ante-natal diet. It seems reasonable to suggest that the lower incidence of dental caries in the deciduous dentition of the fee-paying children might be ascribed to the superior pre-natal diet and general care of the mother in Social Class I.

The deciduous teeth begin to calcify during the fifth and sixth months of intra-uterine life, and by birth are well advanced in development. The deciduous incisors and first molars have completed enamel formation by six months of age and by the end of the first year all deciduous teeth have completed their enamel formation. It can be seen, therefore, that with regard to the deciduous teeth, prenatal environment and the environment during the first year of life may be of considerable importance.

However, the evidence of Coumoulos and Mellanby (1947) relating the surface structure of enamel to the incidence of dental caries, suggests that the enamel formed postnatally may be the more important, since this is the outer enamel. The social differences observed in the incidence of dental caries in deciduous teeth may therefore be more a reflection of the standards of child welfare in the different social groups than of maternal ante-natal diet.

The results presented by Coumoulos and Mellanby showed that, as for the Edinburgh children, those children who attended fee-paying schools had a lower incidence of dental caries than children of the same age attending L.C.C. schools.

Owing to different methods of presenting the data, direct comparison with the data for London children is not possible. Computing d.m.f. values for deciduous canine and molar teeth for London children from the data presented, the private school children have a mean number of d.m.f. teeth of 2.39, compared with a d.m.f. of 4.22 for the L.C.C. school children. The small number of fee-paying five-year old children in the Edinburgh sample did not permit the presentation of the data in one year age groups, and the age range 5 - 8 years was used. However, the difference in d.m.f.

between the private school and L.C.C. school children was greater than that observed in the present study. The difference for the London children was 1.83 d.m.f. teeth and that for Edinburgh children 1.31.

Coumoulos and Mellanby also compared the five year old fee-paying and L.C.C. children with children of the same age living in institutions, when it was found that the institutional children showed the lowest incidence of dental caries. However, they reported that tooth structure, as defined by examination of the tooth surface in the mouth, was noticeably superior in fee-paying children and worst in those living in institutions, while the L.C.C. children occupied an intermediate position. This apparently anomalous situation, in which children with the poorest surface structure of enamel had the lowest incidence of dental caries, was resolved when it was appreciated that between children belonging to the same social group, those with the poorest enamel structure showed the highest incidence of dental caries and vice versa.

It is clear, therefore, that differences other than those of tooth structure must have contributed to the difference in incidence of dental caries between the social extremes of fee-paying and institutional children. Furthermore, these additional factors were clearly capable of nullifying the influence of good structure in the fee-paying children and appear to be related to the environment of the tooth following its eruption into the mouth.

It was concluded by Coumoulos and Mellanby that the post-eruptive diet of the institutional child must be favourable to a low susceptibility to dental caries, since the imperfectly formed teeth could, on the basis of their findings, be expected to show a high susceptibility to attack. In the non-institutional children it was established that the poorer the tooth structure, the higher the incidence of dental caries and therefore the post-eruptive enviwonment in these children must have contained some factor which increased susceptibility to this disease, a factor apparently lacking from the environment of the institutional child.

With regard to the permanent teeth, the values for 14 year old London school children, presented by Mellanby and Mellanby (1953) were recomputed and show the following comparisons between Modern, Technical and Grammar schools in London, in D.M.F. teeth per child.

| | |
|---|---|
| Modern | 3.6 D.M.F. teeth per child |
| Technical | 4.0 D.M.F. teeth per child |
| Grammar | 4.2 D.M.F. teeth per child |

The difference between the Modern and Grammar schools is 0.6 D.M.F. teeth per child and is of much the same order as that found between non-fee-paying and fee-paying children of approximately the same age in Edinburgh, which was 0.7 D.M.F. teeth per child.

When the permanent teeth are compared, an apparently anomalous situation arises. Calcification of the permanent teeth begins at birth with the first molar, and by about eight to nine years of age the enamel of all permanent teeth, except for the third molar, has completed its formation. The admittedly superior environment (in its broadest sense) of the fee-paying children compared with that of the non-fee-paying could be expected to result in teeth of better structural quality and with an increased resistance to dental caries. However, the dental caries rates of the fee-paying children have been shown to be higher than those of the non-fee-paying, and in terms of number of teeth attacked, significantly so.

An examination of the pattern of attack by caries of the individual teeth in these different social groups provides some evidence to explain this apparent contradiction. The data relating to dental caries incidence of the individual teeth revealed differences between fee-paying and non-fee-paying children in the distribution and type of caries. The most distinctive difference was in the proportions of occlusal to other lesions. While the higher incidence of caries involving two or more surfaces, which was seen to exist among fee-paying children, could be explained on the basis of the more extensive dental treatment received by this group, the significantly lower incidence of caries affecting the occlusal surface of premolars and molars was less easily explained. In fact, quite the reverse was expected, since it seemed possible that with more regular dental attention, many deep occlusal fissures might be filled, but which in fact may not have been carious and might never have become carious if left untreated.

In general, the incidence of dental caries of the approximal surfaces was higher in the fee-paying group, with one exception, that of the central incisor which, in both sexes, was higher for the non-fee-paying children.

The observed higher incidence of dental caries of the permanent teeth of fee-paying children, with a higher incidence of the approximal surfaces and a significantly lower incidence of the occlusal surfaces of premolar and molar teeth compared with the non-fee-paying children, is of considerable interest.

The significantly higher incidence of occlusal caries in the premolar and molar teeth in the non-fee-paying children is very suggestive of poorer tooth development.

The greater overall incidence of dental caries in the fee-paying children is due to a higher frequency of cavities involving two or more surfaces, most of which consist of approximal fillings with extension to the occlusal surface. It seems a reasonable assumption that initially these were smooth surface lesions affecting a mesial or distal surface, and that the involvement of the occlusal was largely for reasons concerned in the mechanical restoration of the tooth. The possible error involved in this assumption would seem to be small.

Reid and Grainger (1955) suggest that caries of smooth and pitted surfaces may differ in aetiology and that dental caries of smooth surfaces seems to reflect environmental conditions in the mouth. They noted that the presence of a deep pit or fissure seemed to result in a cavity developing soon after eruption of the tooth.

They compared data obtained by dental examination of school children aged 6 - 17 years in the town of Burlington, Ontario, with similar data derived from Aylmer, Ontario, where the natural water supply contained 1.2 parts per million of fluoride. From this comparison they observed that pitted surfaces showed about the same rate of attack in the fluoride area as in the fluoride-free area, but that the rate of attack by caries of the smooth surfaces was very much lower in both anterior and posterior teeth. It would seem, therefore, that smooth surface caries is more dependent upon post-eruptive environmental factors than caries affecting pits and fissures. The latter would seem to be more dependent upon developmental factors.

It seems reasonable to conclude, then, that the differences between fee-paying and non-fee-paying children in their dental caries experience of the permanent dentition may be due to poorer tooth structure in the non-fee-paying, and a more caries-producing oral and other environment in the fee-paying children. It would seem from this reasoning that the caries promoting factor in the higher social groups is the more potent of these two aetiological factors.

The literature provides considerable evidence to show that factors in the oral environment of the tooth which promote susceptibility to dental caries have their origin in the diet, and further, that those items of diet most clearly implicated are those classed under the general description of "refined carbohydrate", i.e., sugar, white flour and all their various products. It seems not unreasonable then to suppose that dietary differences in these two social groups may provide the answer, and the data reported by the National Food Survey Committee for the year 1953, in which differences in food consumption and expenditure are shown to exist between the various social classes, lends further support to this view.

No certain answer can be given as to why this does not occur in the deciduous teeth between fee-paying and non-fee-paying children living in their own homes, since dietary differences between fee-paying private school children at home and children of the same age living in an institution would seem to be responsible for the lower incidence in the institutional child.

One possible explanation may be offered, however. From the evidence it seems not unreasonable to suppose that in non-institutional children, fee-paying and non-fee-paying alike, the diet following eruption of the teeth is not so very different between the two groups for, in general, rather simple fare is offered to the young child which, because of his great dependence upon parents, is accepted. The difference in incidence of dental caries of the deciduous teeth seen between the non-institutional children at different social levels may therefore be due mostly to differing standards of nutrition during the period of tooth development. However, with the coming of school age the child rapidly acquires increasing degrees of independence while at the same time parental control and supervision is progressively reduced. During the period of the mixed dentition and eruption of permanent teeth, the child can add to his diet much that is his own choice and exclude those items of diet which do not appeal to him.

The results of this study of Edinburgh children are in agreement with those of Mellanby and Coumoulos for London children to a considerable extent, in showing that differences in the incidence of dental caries exist between children from different social levels. As far as it is known, no previous study has compared the distribution of caries of individual tooth surfaces between children belonging to different social groups. These findings, interpreted according to the view of

Reid and Grainger seem to provide further confirmation of the conclusions of Mellanby and Coumoulos.

No direct comparison of the Edinburgh data with those of the literature reviewed has been possible because of differences in presentation of these data.

Savara and Suher (1955), in a study of socio-economic factors and dental caries in children in the age range 2 - 6 years, show that while no association was found between income of the father and dental caries incidence in the child, a negative association was found between standards of parental education and caries. For "frequency of food consumed between meals" and the "consumption of refined carbohydrate", both factors, for which there is good evidence of association with susceptibility to caries (Gustafsson et al., 1954) showed no association in this study. These unexpected results may, however, be explained by the age of the children studied, who had a mean age of 3.9 years. At the younger ages the type of caries expected to predominate in the deciduous teeth is that originating in pit and fissure systems and which has its onset soon after the tooth erupts. As discussed earlier, this type of lesion may be associated more with conditions existing during tooth development, that is, in prenatal life and the first year after birth. On the other hand, lesions associated with factors in the oral environment could be expected to require a longer duration of exposure to produce their characteristic effect. (Reid & Grainger, 1955)

In this event, the negative correlation of standards of parental education with caries incidence in the child may be measuring inditectly standards of ante-natal care and infant welfare, i.e., quality of tooth structure.

As could be expected, frequency of tooth brushing by the child and standards of parental education showed direct association, but the frequency of tooth brushing showed no relationship to dental caries incidence. Good standards of oral hygiene have often been regarded as ineffective in reducing the incidence of dental caries, since those areas of the tooth surface which can be kept clean by the individual are not usually those in which the carious lesion is common. When fee-paying and non-fee-paying children are compared, the standards of hygiene among the fee-paying children are very obviously superior, yet when the incidence of dental caries is compared, the fee-paying children have noticeably higher rates in spite of their better standards of hygiene.

When the average number of D.M.F. teeth per child for the three grades of oral hygiene is compared, it is found that in both sexes the incidence of dental caries is consistently lower for those children whose standard of oral hygiene is good compared with those whose standard was regarded as neglected.

For those children in Group VII, the average difference between boys with good and boys with neglected hygiene is 1.1 D.M.F. teeth. The difference between girls in these categories of oral hygiene is 1.77 D.M.F. teeth. When boys and girls are compared, it is seen that the girls have consistently higher standards of oral hygiene. This is of interest in view of the fact that the incidence of dental caries among girls is consistently higher than among boys. It would seem therefore, that this difference between the sexes in dental caries experience exists in spite of generally higher standards of hygiene of the girls.

It must be stated, however, that while the standards of oral hygiene were assessed for these children, no evidence was obtained to show whether the observed state of the teeth was, in fact, due to the use (or lack of use) of a tooth brush. No inquiry was made of the child, since it was felt that little reliance could be placed upon many of the answers that would have been received. It is therefore not possible to say whether the state of these children's teeth is due to their own efforts, or whether the observed state is due to natural self cleansing. The differences between the fee- and non-fee-paying children suggest, however, that these standards of hygiene are some measure of the use of a tooth brush.

The evidence presented, therefore, permits the conclusions that significant differences in caries experience exist between children from different social levels and, further, that these differences originate in the total environment of the child, personal and social. The prenatal environment in terms of maternal nutrition and the environment of the infant in the first year of life in terms of health and nutrition are of major importance in influencing the structural quality of the deciduous teeth (Toverud, 1949). This present study provides evidence to suggest that these factors contribute largely to the social differences in caries of the deciduous dentition.

The greater susceptibility of the permanent teeth in Social Class I children, in spite of better structure is related to diet following eruption of the teeth as indicated by the pattern of attack of the various tooth surfaces.

Standards of child care all contribute to the final result and therefore it is suggested that maternal knowledge and efficiency appear to be more important than economic factors alone.

# CHAPTER VI

## The influence of family size on the incidence of dental caries in children

Family size can exert a profound influence upon the economic circumstances of the family, and in those families where income is fixed, an increase in size must inevitably result in an alteration in the standards of living in direct proportion to the size of the family. In consequence, the pattern of spending must also change, and it seems reasonable to suppose that this might introduce changes in the dietary pattern.

Lorimer and Roback (1940) made a study of the economics of the family relative to the number of children. They showed that the proportion of family income spent on food rises as the family increases up to three or four children. However, in spite of the rise in proportional expenditure, the nutritional level falls in inverse proportion. It was apparent from the data obtained, that food requirements exerted an urgent pressure on the budget of these families.

In general, it was found that, as the number of children increased, families at given income levels compromised between increased food requirements and other added needs by devoting a larger part of their available resources to food, but at the same time accepting a more restricted diet.

In this country, a survey carried out by Beltram (1949) to assess the level of nutrition among school children, studied the diets of 370 boys in England and Wales. The sample was drawn from families where the chief wage earner had a basic weekly wage of £5.10s.0d. or less.

It appeared from the results that children of unskilled workers and children in families of four or more children tended to eat more of foods such as bread, stews and meat puddings and less of cakes, biscuits, cheese, eggs and fruit, than children of skilled workers and "only" children. It was found that the children of unskilled workers had rather fewer breakfasts containing cooked protein, and supper amounted to a milk drink and/or bread and "spread".

There was also a trend towards a poorer type of meal for children in large families, where a greater percentage of meals of the bread and "spread" type were taken. Also a higher proportion went to bed without supper, than of children in smaller families; and boys in families of four or more children appeared to have, on the average, more vegetable protein and rather less animal protein than only children.

The Annual Reports of the National Food Survey Committee on domestic food consumption and expenditure for 1952 and 1953 showed that the effects of family composition exerted a considerable influence on both food consumption and expenditure. Data were presented for the following five categories of households: (i) Husband, wife and no children, (ii) husband and wife with one, two, three and four or more children. It was seen from the data that for all items of food, consumption (in oz. per head per week) fell consistently in amount with increase in family size. It was recognised that the larger the family the smaller will be the consumption per head because of the smaller needs of children, but analysis of these data indicated that, relative to their needs in terms of energy requirements, larger families consumed less than their share of meat, fish, eggs, cheese, fruit and vegetables, and more than their share of bread and potatoes.

In general, diets of households of up to and including two children appeared to be satisfactory, but for those with three or more children the diet appeared to be lower than recommended for protein, calcium and possibly riboflavin. Scales of allowances were based on those recommended by the British Medical Association's Committee on Nutrition (1950). In conclusion, it was suggested that the nutrients in which larger families with several children are likely to be most vulnerable during a period of rising prices are calcium, protein, iron and riboflavin in that order.

The Chief Medical Officer of the Ministry of Education (1952-53) makes the observation that children from small families tend to be of better physique than those from large ones, especially in the lower social groups.

These data indicate clearly that in spite of the changes and improvements in social and economic conditions of the lower social classes since the war, economic differences between different social levels still exist to a degree that can produce a reduced standard of nutrition with increase in size of family.

Miller and Crombie (1939) in a study of 50 children, 25 of whom were caries-free and 25 showed severe caries, reported that those with severe caries were more often the younger children of a family, and that those who were caries-free were the elder children. These differences were ascribed by the authors to the poorer socio-economic position of the later children in families with relatively fixed incomes. The average weekly income per head of family was 10s.2d. and 10s.6d.

for the two groups respectively.

Berk (1943), in a study of 198 five-year old children in Boston, Mass., also found that the firstborn children had a lower incidence of dental caries than those whose order of birth was fourth or later. The firstborn group had an average of 8.82 deciduous teeth carious, while those whose birth rank was fourth or later had 10.42 carious teeth per child. This result was considered of borderline significance.

## Results

A comparison of dental caries experience was made between children grouped according to their rank order of birth for both the permanent and deciduous teeth.

### Deciduous Dentition

Owing to limitations of numbers, no attempt was made to group the children by single year age groups, and for the deciduous teeth all children between five and eight years of age were aggregated in one group of each sex. The results are presented in Table 21 below.

Table 21

Mean number of decayed, missing and filled deciduous molar and canine teeth of children aged 5 to 8 years, ranked in order of birth

| Birth Rank | Boys | | Girls | |
|---|---|---|---|---|
| | No. of Children | Mean No. of d.m.f. Teeth | No. of Children | Mean No. of d.m.f. Teeth |
| Only child | 66 | 7.21 | 84 | 7.08 |
| 1st with siblings | 111 | 6.32 | 109 | 6.40 |
| 2nd | 176 | 6.37 | 178 | 6.28 |
| 3rd and greater | 304 | 5.85 | 253 | 6.27 |

Non-fee-paying group only.

It can be seen from the tabulated data that the difference between the only child, the first in a family, the second and the third or greater, are small, but that the trend in both sexes is reasonably consistent and suggestive of a real difference. The difference in mean number of d.m.f. teeth between the only child and the firstborn of a family is not statistically significant for either sex. However, the difference between the only children and those whose birth rank is third or over is statistically significant for boys ($t = 2.441$, $p = < .05$) but not for the girls.

Permanent Teeth

Children were ranked by birth, in groups according to the number of teeth erupted, and the mean number of decayed, missing and filled teeth, for each category of birth rank, was calculated for each of the eight "tooth eruption" groups.

The birth order recognised for the total sample was as follows:-

(a) First born, with no siblings

(b) First born of a family

(c) Second born

(d) Third born

(e) Fourth born

(f) Fifth or over fifth in order of birth.

When the tabulated results were examined, it was seen that in all eight tooth eruption groups, the first born (i.e., (a) and/or (b) ) had a consistently higher mean number of decayed, missing and filled teeth compared with that for the fifth born.

In the younger groups, however, the small amount of dental caries experienced resulted in only small differences between the various ranks. However, the differences between the various ranks of birth increased with age, as the total dental caries increased.

The tabulated results for Group VII (25 to 28 permanent teeth erupted) are presented in Table 22. The number of children in Group VIII is too small to permit valid comparison, although they show the same general trend.

Table 22

Mean number of decayed, missing and filled permanent teeth in children ranked in order of birth

| Group VII Birth Rank | Boys | | Girls | |
|---|---|---|---|---|
| | No. of Children | Mean No. of d.m.f. Teeth | No. of Children | Mean No. of d.m.f. Teeth |
| Only child | 79 | 6.14 | 132 | 7.05 |
| 1st with siblings | 179 | 5.72 | 215 | 6.79 |
| 2nd | 149 | 5.48 | 216 | 6.50 |
| 3rd | 87 | 5.55 | 103 | 5.65 |
| 4th | 49 | 5.33 | 44 | 5.50 |
| 5th and over | 35 | 4.69 | 51 | 5.24 |

The differences between the first born and those whose birth order was fifth or more, are well marked and are statistically significant for both sexes. The differences between those within these extreme limits are less marked as might be expected, but with one exception, they are consistent.

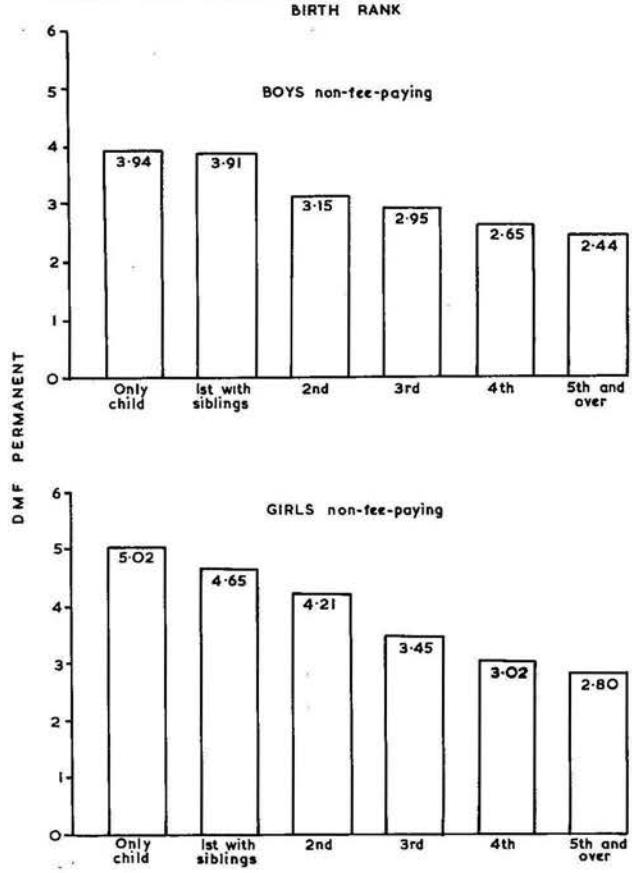
The results tabulated for the entire sample, including all eight groups as one, are presented in Table 23 following and Figure 16, from which it can be seen that differences in mean D.M.F. teeth between the only child and the first of a family are not significant, but are highly significant between the only child and the child whose birth rank was fifth or over.

Table 23

Mean number of decayed, missing and filled permanent teeth in children ranked in order of birth.

| All Groups combined<br>Birth Rank | Boys | | Girls | |
|---|---|---|---|---|
| | No. of Children | Mean No. of D.M.F. Teeth | No. of Children | Mean No. of D.M.F. Teeth |
| Only child | 207 | 3.94 | 280 | 5.02 |
| 1st with siblings | 466 | 3.91 | 467 | 4.65 |
| 2nd | 454 | 3.15 | 547 | 4.21 |
| 3rd | 330 | 2.95 | 300 | 3.45 |
| 4th | 191 | 2.65 | 169 | 3.02 |
| 5th and over | 199 | 2.44 | 204 | 2.80 |

FIGURE 16
AVERAGE D.M.F. PERMANENT TEETH PER CHILDREN ACCORDING TO BIRTH RANK



In Table 24 below, the mean number of decayed, missing and filled permanent teeth of children ranked according to their order of birth in a family is presented for children attending fee-paying schools.

Table 24

Mean number of decayed, missing and filled permanent teeth of children ranked in order of birth. Fee-paying children.

| All Groups combined Birth Rank | Boys | | | Girls | | |
|---|---|---|---|---|---|---|
| | No. of Children | Mean No. of D.M.F. Teeth | Mean Age | No. of Children | Mean No. of D.M.F. Teeth | Mean Age |
| Only child | 39 | 5.08 | 13.21 | 34 | 6.06 | 14.17 |
| 1st with siblings | 64 | 4.94 | 13.41 | 49 | 5.96 | 13.71 |
| 2nd | 43 | 3.88 | 12.33 | 62 | 5.03 | 13.02 |
| 3rd and more than 3rd | 19 | 3.84 | 13.60 | 24 | 4.88 | 13.11 |

The same general trend is seen in children from fee-paying schools as was observed in the other children, but in this instance the differences are not significant.

## Discussion

The National Food Survey Reports indicate that increase in size of family may exert a measurable influence upon family economics and diet. Although a lowering of nutritional standards was not observed for families of less than three children, in Britain it was seen that for all items of diet there was a progressive reduction in amount with each increase in size of family. The findings of Lorimer and Robeck in the United States and of Beltram in this country confirm this general trend.

In the light of these survey findings, the results of comparing the dental caries experience of Edinburgh children by birth rank are of some interest. While the differences observed between each individual rank are not large, they are consistent throughout the groups examined, for boys and girls alike, and what is of particular interest is that, contrary to expectation, similar differences were found among the children from fee-paying schools.

When the crude figures were first examined, it was thought possible that on average, the first born children might be older than those of later birth rank. It was found, however, that when the children were placed in their appropriate age groups, the same trend persisted. The data presented for Group VII confirms this.

The small number of fee-paying children made it necessary to combine all age groups, but when the ages of each rank of birth are compared, it can be seen that differences in age do not seem to account adequately for their rank order, which is in agreement with that for the other social group.

It is of interest that the incidence of dental caries in the deciduous dentition, also shows the same association with birth rank of the child, and that in all instances the "only" child has a higher incidence of dental caries than the first of a family, although in <u>no</u> instance was the difference between the only child and the eldest of a family found to be statistically significant. Since the firstborn of a family was also for a period an "only" child, these findings suggest the possibility that the advent of younger siblings produced changes in the family environment.

The data provide no explanation of the cause of these differences between children of varying order of birth. This is a problem which seems worthy of future investigation. Only tentative suggestions as to the possible cause can therefore be offered.

The survey data, previously discussed, suggests that increasing family size in certain social groups leads to a less lavish, or even to a poorer diet. There is ample evidence to support the view that, in those individuals who subsist on a more restricted diet, the incidence of dental caries is generally low. The findings of Coumoulos and Mellanby on institutional children appear to confirm this view. It is also possible that, with increase in size of family, the characteristics of institutional life are to some extent reproduced on a smaller scale. Not only does the diet become plainer, but the larger the family, the less likely are individual preferences in items of diet to be considered or pandered to.

These findings relating to birth rank and the incidence of dental caries for Edinburgh children are at variance with the results of the two previous studies described, in which the younger children of the family have the highest incidence of caries and the oldest least. There are, however, important differences between the previous studies and this present investigation.

Firstly, the numbers of children are much smaller in both the earlier studies than they are for this present one.

Secondly, the children examined by Miller and Crombie and by Berk were derived from low socio-economic groups. The Boston children are to a great extent selected, since they come only from those families who cannot afford private dental treatment, yet are sufficiently enlightened to appreciate the need for it.

The study of Miller and Crombie was carried out on Tyneside on children from a very low socio-economic group, many of whom were born and reared during a period of economic depression and unemployment and which was very marked in that area.

Orr (1937) showed about the same period of time that in the lower income groups the average diet was considered inadequate for perfect health and that in fact a diet completely adequate for health according to modern standards was reached only at an income level above that of 50 per cent of the population. He commented that, owing to their nutritional needs during growth and development, the effects of poor diet are therefore accentuated in the children. In these circumstances, increase in family size could only depress further the nutritional level of the family and consequently each succeeding child would tend to be reared in even poorer circumstances than those of his immediate predecessor. The pattern of dental caries prevalence observed between the younger and older children in a family may, under these social conditions reflect the effects of poor pre-natal nutrition and sub-optimal standards of nutrition of the infant and child during the period of tooth development with consequent inferior tooth structure.

However, with regard to diet following tooth eruption, it is possible that however poor nutritionally it may have been, it lacked the caries-provoking factors found in the diets of the better off members of the community.

It is possible, then, that the first born children in both these studies had teeth of better structure than their younger siblings and that, in fact, their greater freedom from caries is a reflection of this difference in pre-eruptive or developmental environment of the teeth. But because of the very low socio-economic status of these families, the differences in post-eruptive environment between the first born and the later born children may not have been so very different.

The Edinburgh children, however, were derived from all social classes. In the non-fee-paying children, Social Classes III, IV and V were represented. Furthermore, the effects of school milk and meals at nominal cost, welfare foods, full employment and high wages, all contributed to raise the standards of living from the pre-war level. Differences in nutrition, therefore, were probably not sufficiently great to result in very marked differences in tooth structure or to a degree that would influence susceptibility to dental caries.

The observation of differences in dental caries incidence in the fee-paying children according to birth rank would seem to confirm this view. In consequence, differences in the incidence of caries according to birth rank in the Edinburgh children may be a reflection of changes in the post-eruptive oral environment due to the economics of family size with each increase in family size affecting the level of consumption of those foods classed as luxuries, but owing to better economic circumstances affecting least those items of diet which are essential to health.

It can be concluded, therefore, that differences in social and economic conditions, probably operating through diet and nutrition, exert a by no means negligible influence upon the incidence of dental caries in school children in Edinburgh.

# CHAPTER VII

## The Incidence of Dental Caries in Relation to Maturity

In previous chapters data have been presented to show that differences in dental caries experience existed between children from contrasing socio-economic levels, comparison being made between children attending fee-paying schools with those attending non-fee-paying schools. Selected in this way the children compared were in the main divided into those belonging predominantly to Social Class I and the remainder (the non-fee-paying children) represented Social Classes III, IV and V. This division of the sample distinguished unmistakeably two distinct groups of differing social environments. The information available relating to the occupation of the child's father was in most instances insufficiently precise to discriminate between the various social levels of which the non-fee-paying children were comprised. For this reason these children constituted a socially heterogeneous group.

It is well recognised that differences in both stature and weight of children vary according to socio-economic level and, since such variation is probably related to standards of diet and nutrition, the possibility existed that physical differences within the non-fee.paying group of children might discriminate between the various social strata of which the group was composed, in terms of diet and nutrition.

Clements (1953) examined data relating to heights and weights of British children over the past 70 years. These data show clearly the differences that exist in height and weight between children drawn from upper, middle and lower income groups, and also indicate that children are growing more quickly now than they were some years ago. Furthermore, while these changes have taken place in all social groups, the greatest increases have occurred in the lower income groups, with the result that the disparity between children from upper and lower income groups has now been greatly reduced. Of considerable interest is the fact that during both World Wars this upward trend wasinterrupted, to be continued again after World War I during the inter-war period. This effect of both world wars is interesting, since Sognnaes (1948) showed that during both wars there was a considerable reduction in the prevalence of dental caries in those countries involved. This reduction in caries was considered to be related to dietary changes, particularly those in regard to sugar consumption. He also showed that, at the end of the wars after a delay of some years, the prevalence of dental caries began to increase and continued towards the pre-war level.

For that part of the total sample of children studied which was examined as part of a joint investigation with H. S. Provis and R. W. B. Ellis (who were investigating growth and development of these children) data relating to lying height, nude weight and a clinical assessment of sexual maturity were available. It was decided, therefore, that a comparison of dental caries experience with certain physical measurements of non-fee-paying children should be undertaken in order to see whether the difference in dental caries found between fee-paying and non-fee-paying children would be repeated between children of differing physique.

The literature revealed only two investigations in which the relationship between physique and dental caries was studied. Cunningham (1934), in an investigation of the relation of dental caries to disease, menstrual experience and physical measurements in 11,117 young women aged 15 to 19 years, found some evidence that the tall women showed a higher prevalence of dental caries than those of medium or short stature. This difference was found to be statistically significant.

Discussing these findings, she expresses the view that many of the women of 15-18 years may not yet have attained full stature, and since dental caries increases with age, it was possible that the taller women were also among the oldest in the sample. It is unfortunate that no attempt was made to study the age distribution of these women.

Hurme (1936), in a study of 54 case histories of 1st year students, in which prevalence of caries, height and health records were compared, found that when the number of D.M.F. teeth was compared with height, the relationship, although not well marked, showed the number of D.M.F. teeth to be slightly less in the shorter half of the group. However, when the extremes of the distribution were compared, the short individual had fewer D.M.F. teeth than the tall. Furthermore, since most of the tall individuals happened to belong to the youngest age group, the difference between the tall and the short was obviously not a function of chronological age in this instance.

As discussed earlier in this thesis, the discrepancy between chronilogical and developmental age in individual children can be considerable and in consequence differences can exist between the number of teeth erupted at any given age. Therefore differences in total dental caries experience in children at the same age may be due in part to this. Also, even when all teeth have erupted, some individuals will have had their teeth exposed in the mouth to risk of attack for a longer period than others of the same chronological age.

Boas (1933) presented data to show that in a homogeneous social group, development of the dentition and general physical development as measured by height are associated. Talmers (1952) also observed that children of both sexes who had erupted their second molars early, were usually advanced in both height and weight for their age. Conversely, those children who were late in eruption of the second molars were below average in height and weight. It was also noticed that the relationship between body size and eruption was more marked among the boys than among the girls.

Clearly, then, any association found between prevalence of dental caries and physique might also be explained by differences in the rate of development, rather than by absolute differences in physique.

<u>Methods</u>

As a preliminary step in order to see whether or not any relationship existed between the incidence of dental caries and height and weight, the children were ranked in order of greatest to least height and similarly for weight, for each age and for both sexes separately. Each yearly age group was then divided into thirds and comparison of dental caries experience was made between the greates third and the least third for height and weight separately.

Results

It was found that up to and including the age of 11 years in both sexes the differences in dental caries experience between the tallest and shortest and between the heaviest and the lightest were quite insignificant and inconsistent. However, from 12 to 17 years of age for both sexes the taller children showed a consistently greater number of D.M.F. teeth per child than those who were shorter at the same age, with one exception only; that was in girls aged 17 years, where the shortest girls showed an appreciably greater average number of D.M.F. teeth per girl than the tallest.

When weight and dental caries experience were compared, the heaviest girls showed a consistently higher average number of D.M.F. teeth from 12 to 17 years than the lightest girls, but in boys the data showed less consistency and at 12, 13 and 17 years the lightest boys showed a higher average dental caries experience, but at 14, 15 and 16 showed the same trend as the girls, that is, the heaviest had the greatest mean D.M.F.

Figures 17 and 18 illustrate the differences in D.M.F. between these two groups and the numerical data are presented in Tables XIII and XIV in the Appendix.

It was found that these differences could not be explained entirely on the basis of the numbers of teeth erupted, for the average number of D.M.F. teeth per 100 teeth erupted clearly indicated a higher incidence of caries in the taller and heavier children relative to the number of teeth erupted, compared with the shorter and lighter. Also, the differences

FIGURE 17
D.M.F. FOR TALLEST AND SHORTEST THIRD OF AGE GROUP

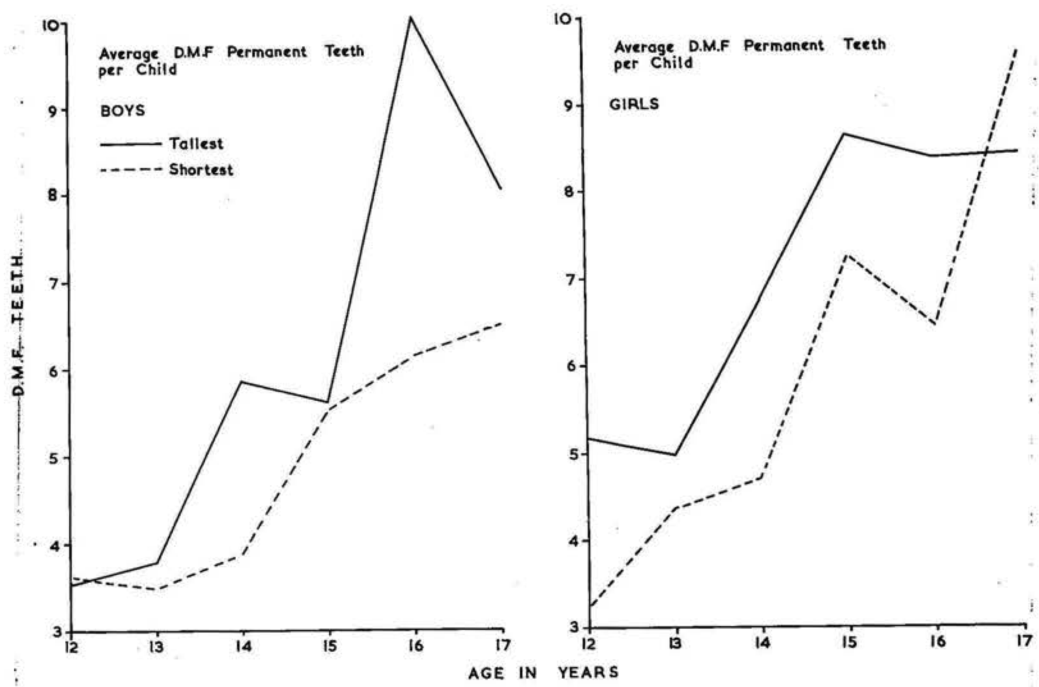
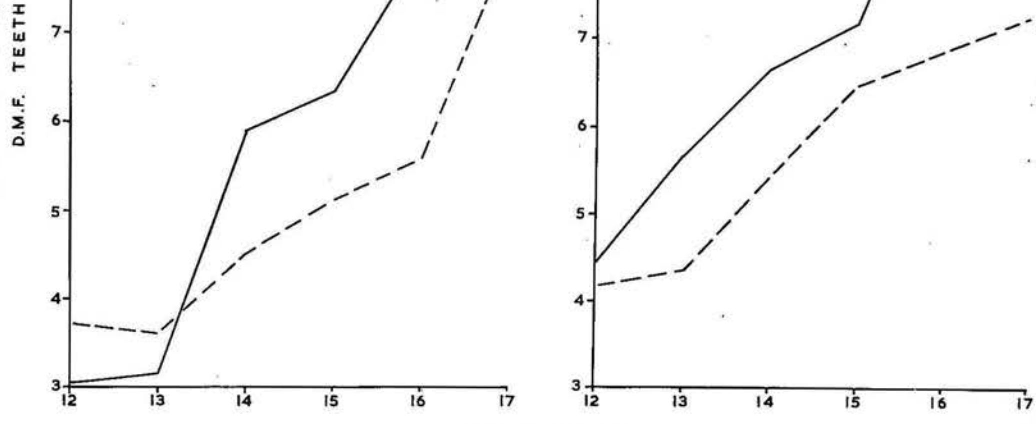



FIGURE 18
D.M.F. FOR HEAVIEST AND LIGHTEST THIRD OF AGE GROUP



in mean age of the children seemed inadequate to explain the differences shown in dental caries experience. As mentioned earlier, it was observed that under 12 years of age the differences in dental caries between tallest and shortest and between heaviest and lightest were both insignificant and inconsistent. This contrast and the age at which notable differences began to appear suggested the possibility that sexual maturation may exert some influence in the incidence of dental caries and be responsible for the differences in caries between groups of contrasting physiques.

The data relating to dental caries prevalence in the total sample of Edinburgh children indicated that the greatest increase in the annual increment of caries was found to occur in girls between the ages of 13 and 14 years and in boys between 15 and 16 years of age - a difference of two years.

Provis and Ellis (1955), in a study of the same sample of Edinburgh children, found that boys began to show evidence of sexual maturation on the average two years later than girls. The median age of pubescence in boys was 13.45 years and in girls 11.30 years, while the median age of adolescence was for boys 15.35 years and for girls 13.35 years.

It is apparent that the peak increase in dental caries and the onset of adolescence correspond in time for both sexes. The suggestion is strong, therefore, that these two events may be related in some way.

For these children a clinical assessment of sexual maturity, made by H. S. Provis, was available. Three grades of maturity were recognised, 'non-pubescent', with no evidence of sexual development, 'adolescent' as an advanced stage of maturity, while the 'pubescent' grade was intermediate. The assessment of maturity in boys was determined by the distribution of pubic and axillary hair, together with degree of development of the genitalia, according to the criteria of Ellis (1946). In girls, the beginning of pubescence was defined by breast enlargement, while the onset of menstruation was taken as the commencement of adolescence.

Therefore for each yearly age group in the upper and lower thirds for height and weight, the data relating to degree of maturation was examined. These data are presented in Table 25 as combined totals for all age groups and are also given in greater detail in Tables XV and XVI in the Appendix.

Table 25

Number of children in the different stages of sexual maturation

| | Boys | | | Girls | | |
|---|---|---|---|---|---|---|
| | NP | PB | AD | NP | PB | AD |
| Tallest | 15 | 51 | 49 | - | 34 | 77 |
| Shortest | 58 | 39 | 18 | 13 | 38 | 60 |
| Heaviest | 14 | 53 | 48 | - | 29 | 82 |
| Lightest | 72 | 32 | 11 | 17 | 40 | 64 |

NP - Non-pubescent
PB - Pubescent
AD - Adolescent

It can be seen from these data that a very much larger proportion of the children in the upper thirds for both height and weight are in a more advanced stage of sexual maturation than those children who happen to be in the lower thirds.

To determine whether an association existed between sexual maturation and the incidence of dental caries, a comparison of dental caries experience was made between children of the same age but at different levels of maturation. For this purpose all the children for whom maturation data were available were taken as the sample.

A preliminary examination of the data had revealed differences in dental caries between pubescent and adolescent children at the same age. However, differences were also observed in the number of teeth erupted in the different maturity groups even at the same age.ø These differences were not large and it was clear that they contributed in part only to the differences in dental caries. For this reason it was decided that comparison between the different maturity grades would be confined to those children who had erupted all permanent second molars. In this way comparison would be made between children of the same age and sex and in approximately an equal stage of dental development to examine the relationship, if any, between sexual maturation and the incidence of dental caries. (ø See Appendix Table XVII)

When these requirements had been met, the distribution of children by age in each of the three maturity gradings was such that only two comparisons could usefully be made:

(1) between 31 pubescent and 35 adolescent girls ages 13 years, and

(2) between 28 pubescent and 28 adolescent boys aged 15 years. The number of children in the non-pubescent group who had erupted all four second molars was, at any age, too small to justify comparison with a pubescent group of equivalent age.

It is generally recognised that attack of the teeth by dental caries is in part a function of the length of time that they are exposed in the mouth after eruption (Palmer et al. 1938). Clements et al. (1953) suggest that eruption of the second permanent molar and puberty are approximately coincident. It was considered possible, therefore, that differences in dental caries between children of the same age who differed only in degree of maturation, might prove to be merely a reflection of the differences in time of eruption of the second molar. For example, it can be expected that the second molars of those children who are adolescent have been erupted in the mouth for a longer period than is the case of those children who are only pubescent at the same age. A second comparison was therefore made between the adolescent and pubescent children of both sexes in which the second molars were excluded from consideration. The results of these comparisons are presented in Tables 26, 27, 28 and 29 following.

Table 26

Mean Number of decayed,
missing and filled teeth
13 year old Girls

| Maturity Grading | No. of Girls | Mean No. Teeth erupted | Mean D.M.F. Teeth |
|---|---|---|---|
| Pubescent | 31 | 27.42 | 4.81 |
| Adolescent | 35 | 27.28 | 5.40 |
| Ungraded Total Edinburgh sample | 151 | 26.92 | 5.58 |

Table 27

Mean Number of decayed,
missing and filled teeth
15 year old Boys

| Maturity Grading | No. of Boys | Mean No. Teeth erupted | Mean D.M.F. Teeth |
|---|---|---|---|
| Pubescent | 28 | 27.68 | 5.68 |
| Adolescent | 28 | 27.53 | 6.54 |
| Ungraded Total Edinburgh sample | 111 | 27.55 | 6.25 |

Table 28

Mean Number of decayed,
missing and filled teeth
Second Molars excluded
13 year old Girls

| Maturity Grading | No. of Girls | Mean D.M.F. Teeth |
|---|---|---|
| Pubescent | 31 | 3.42 |
| Adolescent | 35 | 4.17 |

Table 29

Mean Number of decayed,
Missing and filled teeth
Second Molars excluded
15 year old Boys

| Maturity Grading | No. of Boys | Mean D.M.F. Teeth |
|---|---|---|
| Pubescent | 28 | 4.36 |
| Adolescent | 28 | 4.79 |

It can be seen that those children who are less advanced in maturity have a smaller number of decayed, missing and filled teeth than those who are more mature at the same age. Furthermore, the adolescent children have an average number of D.M.F. teeth which more closely approximates that for the total Edinburgh sample at their age, while the pubescent children have an average more appropriate to a younger age.

The influence of the second molar upon the average number of D.M.F. teeth is considerable, but even when these teeth are excluded, a difference between the two maturity groups remains, which is in the same direction as before.

An examination of the distribution of dental caries of the individual teeth revealed no significant differences in distribution, that is, the pattern of attack in the two groups was substantially the same. The only difference observed was in amount of caries as indicated by the D.M.F. values in Tables 26 and 27. To test the possibility that differences in degree of dental caries might exist between the two maturity groups, the data were arranged to present dental caries measured in terms of affected tooth surfaces. The results indicated, however, that dental caries measured in this way shows differences between the groups equivalent to those observed when using the D.M.F. index. For these data then, the D.M.F. index provides as good a measure of dental caries experience as possible.

Thus far the evidence clearly suggests that degree of sexual maturation is associated in some way with the dental caries experience of the child. It was appreciated, however, that the number of children between whom comparison was made was of necessity small and, taking into account the high variability of dental caries in individuals, it was manifestly desirable that some measure of this possible association be obtained and tested. The comparison of dental caries experience between children in the greatest and least thirds of height and weight had shown that the difference in dental caries in these children might also have been influenced to some extent by differences in both the number of teeth erupted and chronological age. The inter-relationship of these possible factors presented a complicated situation and therefore in an attempt to disentangle the effects of these various factors multiple regression equations were calculated separately for boys and girls, in which the number of D.M.F. teeth was used as the dependent variate and some or all of the following in differing combinations were taken as independent variates:

Height

Weight

Age

Number of teeth erupted

Maturity with stages Non-pubescent<br>Pubescent<br>Adolescent.

For this purpose, within the age range 11-17 years the entire sample for which these data were available was used and consisted of 629 boys and 581 girls.

As might be expected, the number of D.M.F. teeth increased with age and with the total teeth erupted, these two indices being, of course, themselves highly correlated. When the effect of these was discounted, a marked difference appeared between the sexes. Among boys there was a highly significant increase of D.M.F. teeth with maturity, but there was no such effect with girls.

To investigate this further, the regressions were done in another way. In each year of age D.M.F. teeth were used as a dependent variate and the first and second stages of maturation (pubescent and adolescent) as independent variates. From the sums of squares and cross-products of these a pooled regression was done for boys and another for girls. The effect of this is to give a measure of the difference over the range of ages studied in number of D.M.F. teeth between children of like age according to which stage of maturation they had reached.

These regressions confirmed the previous finding, that there was no significant difference between girls of different degrees of maturation. For boys there was no difference between the non-pubescent and pubescent groups, but adolescent boys showed a highly significant excess of D.M.F. teeth, amounting on the average to about 1.8 teeth per boy over boys of like age in the immature and pubescent groups.

Finally, a similar analysis was made in which the number of teeth erupted was used as the dependent variate and the pubescent and adolescent stages of maturation as independent variates. In this way a measure was obtained of the difference in number of teeth erupted between children of the same age according to which stage of maturity they had reached.

These regressions for both sexes showed that the number of teeth erupted was significantly associated with the stage of pubescence, but not with adolescence.

Discussion

It has been shown that differences in dental caries exist between those children who are tallest and heaviest and those who are shortest and lightest in the same yearly age group. However, these differences in physique could not be ascribed only to differences in standards of nutrition, if at all, and in consequence the original objective of this comparison, which was to discover whether differences in physique might discriminate between differing social levels, has not been achieved. It can be seen from the data presented in the Appendix, Tables XIII and XIV, that the tallest and heaviest children were on average fractionally older and had a greater number of teeth erupted. In addition, it was found that the great majority of the tallest and heaviest children had reached a more advanced stage of maturity than those who were shortest and lightest.

With regard to the differences in dental caries between these children, it was appreciated that these differences could be due to either the greater number of teeth erupted, or to the slightly greater age of the tallest and heaviest children, or to both of these factors. However, neither of these seemed adequate to explain fully the observed differences in dental caries, although it was recognised that they could contribute in part. There remained, therefore, the generally more advanced maturity of the taller and heavier children as a possible factor in their greater prevalence of dental caries. It had also been observed that no consistent differences in caries experience existed between these two groups of children of contrasting physique up to 11 years of age, but that major differences were only found in the age group

12-17 years, that is, during the period from puberty to adolescence. Furthermore, the data relating to the incidence of dental caries in the total sample of Edinburgh children indicated that the greatest annual increment of caries corresponded in time with the onset of adolescence in both sexes.

These facts therefore suggested that sexual maturation and susceptibility to caries may be associated in some way. A comparison between adolescent and pubescent children of the same chronological age, who had erupted all their second molars, revealed differences in dental caries for both sexes that seemed only attributable to differences in degree of sexual maturation, and further indicated that these differences involved the whole dentition, not only the more recently erupted second molars.

However, Parfitt and Parfitt (1954), in a study of the caries experience of a number of individuals from childhood to middle age, as derived from the records of private practice, presented data which showed no change in the caries incidence rate between the ages 6 - 21 years, and commented that, while it has been suggested that puberty may have some influence on caries incidence rate, the data examined by them in their study did not show any such change. Of the 60 cases studied in this age range, 20 showed no change in caries incidence rate, but the remaining 40 individuals showed variations in the caries rate during this period, as many showing a decrease as an increase. They concluded therefore that puberty did not affect the caries incidence rate measurably

The data provided by this study are insufficient to show what the mechanism involved in this phenomenon may be, but these facts, together with evidence from other studies, suggest a possible explanation.

Boas (1933) presented data showing that in a homogeneous social group, development of the dentition and general physical development as measured by height are associated. He demonstrated that early dentition was related to early increase in stature.

Talmers (1952) also observed that children of both sexes who had erupted their second molars early were usually advanced in both height and weight for their age. Conversely, she found that those children who were late in eruption of the second molars were below average in height and weight.

Clements et al. (1953) found that there was a trend towards the earlier eruption of the lower C, $PM_1$ and $M_2$ teeth in those children who showed physical signs of puberty compared with those who showed no signs of puberty.

The data for Edinburgh children indicated that the tallest (and heaviest) children had a consistently greater number of teeth erupted than the smallest (and lightest) at approximately the same age, and are therefore in agreement with these other three studies. Also, the data given in Appendix Table XVII, showing the average number of teeth found at various stages of physical maturation in both boys and girls, would seem to confirm the view that tooth eruption and general physical development are closely related.

Of particular interest are the findings of Ellis (1946) in a study of height and weight in relation to onset of puberty in boys aged 11 - 16 years. He found that not only were boys of a higher maturity group heavier and taller than boys of the same age in a lower maturity group, but that differences between the growth curves could be demonstrated as far back as the sixth year. There is thus good evidence that general physical development and eruption of teeth are associated, and further that those children who mature early have been early in general physical development from a much earlier age, while those in whom the onset of puberty is late have been late in general physical development throughout their early years.

It seems possible to suggest, therefore, that in terms of dental development, those who mature late (e.g. in this study, boys who at 15 are classed as pubescent) may have been late in eruption of their teeth throughout their whole period of dental development. In consequence their teeth would have been exposed to risk of attack by dental caries for a shorter period than in the case of those children who have erupted their teeth at the usual times or earlier.

While the differences in decayed, missing and filled teeth between pubescent and adolescent children of the same age could be explained in terms of differences in times of dental development, the possibility exists that these differences in caries experience may be dietary in origin. The period of sexual maturity is accompanied by a rapid acceleration in growth and in consequence nutritional needs are increased, together with corresponding increase in appetite. Widdowson (1947) presents data from which it is apparent that caloric intake reaches a peak for boys at 15 years of age and for girls at 14 years.

Her data relating to total sugar consumption of children is also of some interest, showing that in boys, the highest average intake was 37.7 ounces per week at 15 years of age, and in girls 26.0 ounces per week at the age of 14 years. Total sugar consumption included sugar taken as such, sweets including chocolate, jams, cakes, biscuits, sugar in puddings and in cooked fruit. It was also found that up to the age of eight, differences in sugar consumption between the sexes were negligible, but from nine years upwards boys consumed more than girls and at 15 they were eating nearly twice as much. Between 15 and 18 years boys ate more than twice as much as girls of similar ages.

A finding of considerable importance was the very great variation in food consumption of children at the same age and the fact that these extreme variations were compatible with normal physical development. Ellis (1951), commenting upon this observation regarding variations in food consumption in individual children of the same age, poses the question as to whether maturity grading of children in such a study might not reveal less variation in calorie intake in relation to stage of maturity reached than was observed when the children were grouped by chronological age.

Since an increased intake of refined carbohydrate, especially sugar in sticky form between meals, has been shown to be associated with an increase in susceptibility to dental caries (Gustafsson et al. 1954), the high consumption of these items of diet by children in the 13 - 15 years old age group suggests another possible explanation of the differences in dental caries found between pubescent and adolescent children of the same age. That is, those who mature physically early may then have subsisted for a longer period upon a diet containing a high level of refined carbohydrates than those of the same age who matured later. Gustafsson et al. (1954) clearly demonstrated the rapidity with which susceptibility to dentalcaries could be altered by increasing or decreasing the intake of sugars in certain forms, even in adults. These writers also pointed out that similar dietary changes in children might be expected to produce even more marked differences in susceptibility.

Although two quite different possible explanations may be offered to account for the differences in dental caries experience found in this study between pubescent and adolescent children, these explanations are not mutually exclusive. It is therefore possible that both differences in time of development of the dentition and differences in susceptibility due to dietary changes may both play their part in producing the results described in this study.

From the multiple regression analysis confirmation of previous findings in this study was obtained that for boys, sexual maturity and dental caries incidence are associated and more precisely that this association is related to adolescence but not to pubescence. Furthermere, the differences in D.M.F. teeth between adolescent and pubescent boys of the same chronological age attributable to maturity alone was 1.8 teeth. For girls, however, the differences in dental caries experience between those who are adolescent and those who are pubescent at the same age were not found to be significantly associated with stage of maturity.

This difference between the sexes was not expected since the previous evidence suggested that, if in fact sexual maturity and dental caries incidence were associated, it would have been so for both sexes inasmuch as:-

1. For the total Edinburgh sample the greatest increment of dental caries was found to correspond in time with the onset of adolescence in both sexes, i.e., between 13 and 14 years in girls and 15 and 16 in boys. It was seen, however, that the increase in D.M.F. teeth in boys between 15 and 16 years was greater than the increase in girls between 13 and 14 years.

2. The tallest and heaviest thirds of each yearly age group showed a significantly greater proportion of children in more advanced stages of maturity than those in the least thirds. This was true for both sexes.

3. The comparison between pubescent and adolescent children of the same chronological age, who had also erupted all their second permanent molars, indicated that there was a higher incidence of caries in the adolescent children of both sexes and that this difference in caries affected the whole dentition in both sexes.

It is recognised that individual variations in dental caries incidence are considerable and result in large standard deviations. Consequently because of this variability any difference in D.M.F. rates between groups of individuals must be large to be statistically significant. Taking all the evidence into account, the possibility exists that the differences in dental caries experience observed between girls at different stages of maturation may, in fact, be associated with maturity in much the same way as for boys, even if not of such magnitude as to show a statistically significant relationship.

It is concluded, therefore, from the evidence obtained that adolescence in boys is associated with a higher dental caries incidence than is found in pubescent boys of the same age.

It is suggested that this may be due to either a longer total exposure of the teeth in the mouth or to dietary factors associated with adolescence, or to a combination of both factors together.

Finally the regressions for both sexes provided statistical evidence that the number of teeth erupted was associated with pubescence. This confirms the observations made from the data presented in the Appendix - Table XVII - and also those of Clements et al. (1953).

## SUMMARY and CONCLUSIONS

The data presented in this thesis were derived from the examination of 4,034 children attending Edinburgh schools. For 1,730 of these children certain physical measurements were available.

In addition, 224 pairs of twins were also examined.

In measuring dental caries in these children, the D.M.F. index has generally been used.

Because of the discrepancy between chronological and developmental age in individual children, the children were grouped according to the number of teeth they had erupted in order to achieve a closer approximation to developmental age.

### The Incidence of Dental Caries

Data relating to the incidence of dental caries in Edinburgh children has been presented by age and sex and also by "tooth-eruption" group for both sexes.

Where possible, comparisons with other British data have been made, but this was limited owing to differences in methods of presentation of the data.

### Sex Differences

Differences in dental caries incidence between the sexes are demonstrated and discussed. The fact that such differences have been observed in remains from past historical periods and in present day primitive people, as well as in modern civilised races, suggests that these differences are constitutional in origin.

Part of these differences are due to differences in length of exposure of the teeth in the mouth, as a result of the earlier eruption of permanent teeth in girls, compared with boys. However, when this effect is discounted, differences in dental caries between the sexes remain which do not seem capable of explanation by environmental differences alone.

It is concluded therefore that part of the difference in dental caries found between the sexes is constitutional in origin.

Twin Study

A study of dental caries in 96 monozygous and 128 dizygous like-sex twins revealed a greater similarity in dental caries experience in monozygous than in dizygous pairs. This difference was not statistically significant, but the data clearly revealed that the influence of environment was significantly greater than that of genetic factors in the aetiology of this disease.

Comparisons of the data from this study with those of two previous studies showed such a measure of agreement that it was concluded that the greater similarity observed in monozygous twins was a true effect and not merely a chance occurrence, and therefore that a genetic influence exists in the aetiology of dental caries.

Further, it was also concluded that environmental factors in dental caries incidence were of greater importance than constitutional factors.

In this particular study, the use of matched control children greatly facilitated the analysis and final conclusions.

Socio-economic Factors

Socio-economic factors in the incidence of dental caries have been demonstrated.

It was shown that in the deciduous dentition children from predominantly Social Class I families had a lower incidence of dental caries than those children from Social Classes III, IV and V. The possible reasons for this are discussed and the suggestion made that these differences reflect the higher standards of pre-natal care of the mother and of child welfare during the first year of life found in Social Class I compared with lower social classes.

In permanent teeth, however, the child from the upper social classes has the higher incidence of caries.

Differences in the proportions of permanent tooth surfaces attacked by caries were found between children of contrasting social groups.

Children from Social Class I families showed a significantly higher proportion of attacked interproximal surfaces and a significantly lower proportion of lesions originating in pit and fissure systems of the occlusal surfaces of premolar and molar teeth than children from the lower social levels. As far as is known, these differences in the pattern of caries of the various tooth surfaces in contrasting social groups have not previously been reported.

The implications of this finding are discussed and it is suggested that they reflect different aetiological factors; the excess of pit and fissure lesions probably represent poorer tooth formation and structure in those children from lower social groups, while the higher incidence of lesions involving the smooth interproximal surfaces probably reflects the effect of a caries-provoking factor in the diet of the 'better off' social groups.

These data suggest, therefore, that in the permanent dentition tooth structure plays a subordinate role in susceptibility to dental caries, and that those factors operating through the oral environment of the tooth exert the greatest influence.

Family Size and the Incidence of Dental Caries

When children were grouped according to their rank order of birth, a steady decline in D.M.F. teeth was seen to occur from the firstborn child to the later born children, and the lower the order of birth, the lower the incidence of dental caries was found to be. This finding was consistent for boys and girls separately, for the deciduous and permanent teeth and for both the fee-paying and non-fee-paying children.

These findings were compared with those of two previous studies in which the reverse relationship between birth rank and dental caries incidence was found. The differences between these studies and the present one were discussed.

It was suggested that the differences in dental caries found between children of different rank orders of birth are probably dietary in origin, the lower incidence of dental caries in the later born child being a reflection of the changes which have been shown to occur in the family dietary with increase in family size. Furthermore, these differences seem to be clearly related to the direct effect of diet upon the oral environment of the tooth.

These results indicate that susceptibility to dental caries can respond in a sensitive manner to relatively small changes in the dietary.

## Standards of Oral Hygiene

Standards of oral hygiene, as defined in this study, would appear to exert some influence on the incidence of dental caries in both sexes.and the two contrasting social groups.

This effect was clearly limited, since in children who attended fee-paying schools, the standards of oral hygiene were undoubtedly superior, yet they had a higher incidence of dental caries than non-fee-paying school children. Also, girls have a higher incidence of dental caries than boys, on the average, in spite of their superior standards of hygiene.

It can be concluded, therefore, that while standards of hygiene are related to dental caries incidence, this influence is limited in effect.

## Sexual Maturation

From the evidence obtained in this investigation it can be concluded that earlier sexual maturation is associated with an increased susceptibility to dental caries in boys.

Possible reasons for this are discussed.

For girls, the relationship of dental caries incidence with stage of maturation was not statistically significant.

Finally, it was found in both sexes, that those children who reach the stage of pubescence early have a greater number of permanent teeth erupted than non-pubescent children of the same age.

## Further Investigations

This study has revealed certain problems that seem worthy of further investigation.

1. The marked similarity in the results of the study of twins with those of the two previous studies reviewed suggests

that a longitudinal study of monozygous and dizygous twins together with matched control children might provide more precise information regarding the possible influence of hereditary and environmental factors in the causation of dental caries.

2. The differences found between fee-paying and non-fee-paying children in the distribution of carious lesions of the various tooth surfaces suggest that further study of the relationship of caries of pit and fissure systems and caries of the smooth surfaces in relation to diet and nutrition would be profitable.

3. The finding that standards of oral hygiene appear to exert some limited influence upon dental caries incidence was unexpected, but the practical implications of this make its further investigation a necessity.

4. While the data show clearly that sexual maturity and dental caries incidence in boys are associated, they provide no direct evidence to show what the mechanism of this effect may be. Furthermore, no statistically significant evidence was obtained to indicate that a similar relationship existed for girls, although such other evidence as was obtained suggested that this was so.

This problem would seem worthy of further investigation, but would necessitate a long term longitudinal study in which growth and development and possible dietary factors associated with dental caries could be examined more closely. The difficulties of such a study would be considerable.

5. Finally, one of the implications of the study of maturity in relation to dental caries is that those children

who mature early have been advanced in growth and development from a much earlier age. An investigation into the possible relationship of early and late eruption of the permanent teeth and dental caries might be expected to provide confirmation or otherwise of this hypothesis, that early eruption is associated with a higher incidence of dental caries than late eruption.

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A P P E N D I X

Table I

Deciduous canine teeth caries-free, decayed or filled and missing in 1,396 Edinburgh school children aged 5.00 - 8.99 years, both sexes combined.

| Age | Number of Children | Caries-free | Missing | Decayed and Filled |
|---|---|---|---|---|
| | | % | % | % |
| 5.00 - | 102 | 88.73 | 1.23 | 10.04 |
| 5.50 - | 177 | 91.38 | 0.14 | 8.48 |
| 6.00 - | 182 | 86.81 | 0.82 | 12.37 |
| 6.50 - | 188 | 86.57 | 0.80 | 12.63 |
| 7.00 - | 162 | 83.95 | 1.70 | 14.35 |
| 7.50 - | 179 | 80.03 | 6.56 | 13.41 |
| 8.00 - | 212 | 75.47 | 6.37 | 18.16 |
| 8.50 - 8.99 | 194 | 71.52 | 11.98 | 16.50 |

Table II

Distribution by age and sex of 4,034 Edinburgh children examined dentally

| Age in Years | No. of Children examined | | |
|---|---|---|---|
| | Male | Female | Total |
| 5 | 135 | 144 | 279 |
| 6 | 200 | 170 | 370 |
| 7 | 170 | 171 | 341 |
| 8 | 204 | 202 | 406 |
| 9 | 192 | 193 | 385 |
| 10 | 183 | 204 | 387 |
| 11 | 207 | 218 | 425 |
| 12 | 199 | 205 | 404 |
| 13 | 123 | 151 | 274 |
| 14 | 117 | 133 | 250 |
| 15 | 111 | 119 | 230 |
| 16 | 69 | 90 | 159 |
| 17 | 62 | 62 | 124 |
| All Ages | 1,972 | 2,062 | 4,034 |

Table III

Mean Age of Eruption Groups I to VIII

| GROUP | Males | | | Females | | |
|---|---|---|---|---|---|---|
| | Number Examined | Mean Age (Yrs.) | Standard Deviation | Number Examined | Mean Age (Yrs.) | Standard Deviation |
| I | 108 | 6.20 | 0.63 | 114 | 6.14 | 0.56 |
| II | 193 | 7.00 | 0.79 | 145 | 6.74 | 0.74 |
| III | 358 | 8.61 | 1.18 | 323 | 8.26 | 1.05 |
| IV | 273 | 10.03 | 1.20 | 253 | 9.46 | 1.05 |
| V | 139 | 11.10 | 1.10 | 140 | 10.54 | 1.12 |
| VI | 176 | 12.24 | 1.55 | 217 | 11.89 | 1.70 |
| VII | 585 | 14.13 | 1.80 | 765 | 13.89 | 1.87 |
| VIII | 34 | 16.93 | 0.76 | 28 | 16.66 | 0.91 |

Table IV

Mean D.M.F. Teeth per child by age and sex
Edinburgh school children

| Age | BOYS | | | GIRLS | | |
|---|---|---|---|---|---|---|
| | No. of Boys examined | Mean D.M.F. per child | Standard Deviation | No. of Girls examined | Mean D.M.F. per child | Standard Deviation |
| 5.00 - 5.99 | 135 | .12 | .52 | 144 | .19 | .59 |
| 6.00 - 6.99 | 200 | .65 | 1.14 | 170 | .70 | 1.15 |
| 7.00 - 7.99 | 170 | 1.69 | 1.46 | 171 | 2.13 | 1.54 |
| 8.00 - 8.99 | 204 | 1.83 | 1.62 | 202 | 2.31 | 1.57 |
| 9.00 - 9.99 | 192 | 2.20 | 1.71 | 193 | 2.64 | 1.69 |
| 10.00 - 10.99 | 183 | 2.64 | 1.83 | 204 | 3.12 | 2.26 |
| 11.00 - 11.99 | 207 | 3.41 | 1.98 | 218 | 4.17 | 2.77 |
| 12.00 - 12.99 | 199 | 4.10 | 2.70 | 205 | 4.71 | 3.00 |
| 13.00 - 13.99 | 123 | 4.47 | 3.69 | 151 | 5.58 | 3.29 |
| 14.00 - 14.99 | 117 | 5.15 | 3.00 | 133 | 7.11 | 3.60 |
| 15.00 - 15.99 | 111 | 6.23 | 3.73 | 119 | 7.73 | 4.05 |
| 16.00 - 16.99 | 69 | 7.97 | 3.86 | 90 | 8.63 | 4.06 |
| 17.00 - 17.99 | 62 | 8.11 | 4.51 | 62 | 9.11 | 4.92 |

Table V

Mean number D.M.F. Teeth per child

| GROUP | Boys | | | Girls | | |
|---|---|---|---|---|---|---|
| | Number Examined | Mean D.M.F. Teeth | Standard Deviation | Number Examined | Mean D.M.F. Teeth | Standard Deviation |
| I | 108 | 0.29 | 0.71 | 114 | 0.23 | 0.60 |
| II | 193 | 1.03 | 1.31 | 145 | 1.01 | 1.23 |
| III | 358 | 1.77 | 1.52 | 323 | 2.20 | 1.58 |
| IV | 273 | 2.27 | 1.65 | 253 | 2.54 | 1.63 |
| V | 139 | 2.89 | 1.86 | 140 | 3.14 | 1.88 |
| VI | 176 | 3.69 | 2.38 | 217 | 4.02 | 2.90 |
| VII | 585 | 5.61 | 3.47 | 765 | 6.42 | 3.76 |
| VIII | 34 | 9.35 | 4.11 | 28 | 10.46 | 5.27 |

Table VI

Dental Caries Incidence in the different classes of Teeth

| | TOOTH | TOOTH GROUPS I | II | III | IV | V | VI | VII | VIII |
|---|---|---|---|---|---|---|---|---|---|
| | | % | % | % | % | % | % | % | % |
| BOYS | | | | | | | | | |
| $I_1$ | Max. | | | | 1.7 | 2.9 | 6.6 | 15.5 | 35.3 |
| | Mand. | | | | | | | | 1.1 |
| $I_2$ | Max. | | | 0.3 | 2.3 | 4.4 | 8.6 | 12.2 | 31.3 |
| | Mand. | | | | | | | | 0.6 |
| C | Max. | | | | | | | 1.1 | 4.4 |
| | Mand. | | | | | | | 0.5 | |
| $PM_1$ | Max. | | | | 1.7 | 3.9 | 5.9 | 7.8 | 25.4 |
| | Mand. | | | | | 1.0 | 1.0 | 2.5 | 5.9 |
| $PM_2$ | Max. | | | | | 1.9 | 5.9 | 10.3 | 30.9 |
| | Mand. | | | | | 8.8 | 4.7 | 7.7 | 16.2 |
| $M_1$ | Max. | 18.8 | 31.7 | 46.0 | 58.9 | 68.2 | 68.2 | 74.2 | 89.7 |
| | Mand. | 10.6 | 23.5 | 42.0 | 48.7 | 59.0 | 69.6 | 73.1 | 86.8 |
| $M_2$ | Max. | | | | | 15.0 | 24.4 | 41.8 | 67.7 |
| | Mand. | | | | | 11.6 | 24.0 | 38.8 | 63.2 |
| GIRLS | | | | | | | | | |
| $I_1$ | Max. | | | 0.8 | 1.4 | 6.4 | 13.2 | 17.8 | 41.1 |
| | Mand. | | | | | | | | 1.2 |
| $I_2$ | Max. | | | 0.7 | 1.6 | 3.6 | 13.0 | 14.6 | 30.4 |
| | Mand. | | | | | | | | 0.9 |
| C | Max. | | | | | | 0.6 | 1.9 | 8.9 |
| | Mand. | | | | | | 0.5 | 0.4 | 5.5 |
| $PM_1$ | Max. | | | | 4.2 | 3.9 | 6.8 | 12.3 | 21.4 |
| | Mand. | | | | | | 0.5 | 1.8 | 5.4 |
| $PM_2$ | Max. | | | | | 5.5 | 7.8 | 12.1 | 41.1 |
| | Mand. | | | | | | 2.3 | 10.5 | 28.6 |
| $M_1$ | Max. | 12.8 | 30.7 | 56.4 | 61.7 | 69.3 | 69.0 | 78.6 | 80.4 |
| | Mand. | 8.9 | 23.9 | 52.1 | 58.8 | 68.2 | 73.0 | 80.5 | 85.7 |
| $M_2$ | Max. | | | | | 20.0 | 30.2 | 47.6 | 80.4 |
| | Mand. | | | | | 16.7 | 22.3 | 48.4 | 82.1 |

Table VII

Percentage of Deciduous Teeth Carious
in Edinburgh Children

| Age | Boys | | Girls | |
|---|---|---|---|---|
| | No. of Teeth | % Carious | No. of Teeth | % Carious |
| **Second Molar** | | | | |
| 5 years | 540 | 64.6 | 576 | 56.6 |
| 6 " | 800 | 66.4 | 680 | 64.8 |
| 7 " | 680 | 64.0 | 684 | 69.3 |
| 8 " | 816 | 66.4 | 808 | 75.4 |
| **First Molar** | | | | |
| 5 years | 540 | 57.9 | 576 | 47.9 |
| 6 " | 800 | 60.7 | 680 | 60.8 |
| 7 " | 680 | 63.9 | 684 | 65.9 |
| 8 " | 816 | 65.2 | 808 | 73.1 |
| **Canine** | | | | |
| 5 years | 540 | 10.9 | 576 | 8.3 |
| 6 " | 800 | 14.0 | 680 | 12.5 |
| 7 " | 680 | 14.8 | 684 | 21.5 |
| 8 " | 816 | 22.9 | 808 | 30.1 |
| **First and Second Molars and Canines together** | | | | |
| 5 years | 1,620 | 44.5 | 1,728 | 37.6 |
| 6 " | 2,400 | 47.0 | 2,040 | 46.0 |
| 7 " | 2,040 | 47.5 | 2,052 | 52.2 |
| 8 " | 2,448 | 51.5 | 2,424 | 59.5 |

Table VIII

Duration of Exposure of Teeth in the Mouth

| Tooth | Boys: Duration of exposure in the mouth at ages:- | | | | Girls: Duration of exposure in the mouth at ages:- | | | |
|---|---|---|---|---|---|---|---|---|
| | 10.5 yrs. | 12.5 yrs. | 14.5 yrs. | 16.5 yrs. | 10.5 yrs. | 12.5 yrs. | 14.5 yrs. | 16.5 yrs. |
| **Maxilla** | | | | | | | | |
| $I_1$ | 5.54 | 9.54 | 13.54 | 17.54 | 5.62 | 9.62 | 13.62 | 17.62 |
| $I_2$ | 3.72 | 7.72 | 11.72 | 15.72 | 4.24 | 8.24 | 12.24 | 16.24 |
| C | - | 1.44 | 5.44 | 9.44 | - | 2.48 | 6.48 | 10.48 |
| $PM_1$ | - | 3.62 | 7.62 | 11.62 | - | 4.14 | 8.14 | 12.14 |
| $PM_2$ | - | 2.86 | 6.86 | 10.86 | - | 3.30 | 7.30 | 11.30 |
| $M_1$ | 8.26 | 12.26 | 16.26 | 20.26 | 8.40 | 12.40 | 16.40 | 20.40 |
| $M_2$ | - | - | 4.36 | 8.36 | - | - | 4.82 | 8.82 |
| **Mandible** | | | | | | | | |
| $I_1$ | 6.98 | 10.98 | 14.98 | 18.98 | 7.26 | 11.26 | 15.26 | 19.26 |
| $I_2$ | 5.48 | 9.48 | 13.48 | 17.48 | 5.80 | 9.80 | 13.80 | 17.80 |
| C | - | 2.70 | 6.70 | 10.70 | 0.68 | 4.68 | 8.68 | 12.68 |
| $PM_1$ | - | 2.82 | 6.82 | 10.82 | - | 3.36 | 7.36 | 11.36 |
| $PM_2$ | - | 1.68 | 5.68 | 9.68 | - | 2.22 | 6.22 | 10.22 |
| $M_1$ | 8.18 | 12.18 | 16.18 | 20.18 | 8.36 | 12.36 | 16.36 | 20.36 |
| $M_2$ | - | - | 4.46 | 8.46 | - | 1.18 | 5.18 | 9.18 |
| Grand Total | 38.16 | 77.28 | 134.10 | 190.10 | 40.36 | 85.04 | 141.86 | 197.86 |

Table IX

Mean ages of Monozygous and Dizygous Twins and their Controls

| Group Statistic | 0 | | I | | II | | III | | IV | | V | | VI | | VII | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | M | N | M | N | M | N | M | N | M | N | M | N | M | N | M |
| MZ | 16 | 6.01 | 14 | 6.39 | 16 | 6.80 | 58 | 8.25 | 24 | 9.81 | 14 | 10.74 | 16 | 11.50 | 34 | 13.96 |
| CM | 8 | 6.00 | 6 | 6.18 | 8 | 6.98 | 29 | 8.26 | 12 | 9.79 | 7 | 10.74 | 8 | 11.52 | 17 | 13.97 |
| MZ/C | 16 | 6.00 | 12 | 6.23 | 16 | 6.89 | 58 | 8.25 | 24 | 9.80 | 14 | 10.74 | 16 | 11.51 | 34 | 13.96 |
| DZ | 14 | 5.52 | 24 | 6.44 | 38 | 7.26 | 56 | 8.56 | 38 | 10. 22 | 28 | 11.41 | 20 | 11.48 | 38 | 13.89 |
| CD | 7 | 5.54 | 12 | 6.42 | 19 | 7.10 | 28 | 8.55 | 19 | 10.29 | 14 | 11.31 | 10 | 11.46 | 19 | 13.88 |
| DZ/C | 14 | 5.53 | 24 | 6.43 | 38 | 7.18 | 56 | 8.56 | 38 | 10.26 | 28 | 11.36 | 20 | 11.47 | 38 | 13.88 |

MZ - Monozygous twin pairs

DZ - Disygous twin pairs

CM - Children matched with MZ

CD - Children matched with DZ

MZ/C - Monozygous control pair

DZ/C - Dizygous control pair

N - Number of individual children

M - Mean

Table X

Mean number of D.M.F. permanent teeth of Monozygous and Dizygous Twins and their Control Pairs, and of Edinburgh School Children.

| Group | I | | II | | III | | IV | | V | | VI | | VII | | All Groups | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Statistic | N | M | N | M | N | M | N | M | N | M | N | M | N | M | N | M |
| Edinburgh School Children | 222 | 0.26 | 338 | 1.02 | 681 | 1.98 | 526 | 2.40 | 279 | 3.02 | 393 | 3.87 | 1350 | 6.07 | 3789 | 3.58 |
| MZ | 14 | 0.07 | 16 | 0.56 | 58 | 1.79 | 24 | 2.83 | 14 | 2.93 | 16 | 3.19 | 34 | 6.38 | 176 | 2.79 |
| DZ | 24 | 0.25 | 38 | 1.61 | 56 | 2.11 | 38 | 2.42 | 28 | 2.82 | 20 | 3.65 | 38 | 5.18 | 242 | 2.59 |
| MZ/C | 12 | 0.00 | 16 | 0.88 | 58 | 1.85 | 24 | 2.33 | 14 | 2.50 | 16 | 3.19 | 34 | 6.29 | 174 | 2.74 |
| DZ/C | 24 | 0.33 | 38 | 1.53 | 56 | 2.30 | 38 | 2.47 | 28 | 2.36 | 20 | 4.25 | 38 | 5.40 | 242 | 2.66 |

Table XI

Mean number of d.m.f. deciduous teeth of Monozygous and Dizygous Twins and their Controls

| Group Statistic | 0 | | I | | II | | III | | All Groups | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | M | N | M | N | M | N | M | N | M |
| MZ | 16 | 2.25 | 14 | 6.10 | 16 | 5.94 | 44 | 6.11 | 90 | 5.39 |
| MZ/C | 16 | 3.63 | 14 | 6.10 | 16 | 4.81 | 44 | 6.25 | 90 | 5.50 |
| DZ | 14 | 5.07 | 24 | 4.54 | 38 | 5.21 | 40 | 6.53 | 116 | 5.51 |
| DZ/C | 14 | 5.43 | 24 | 5.00 | 38 | 5.79 | 40 | 6.30 | 116 | 5.76 |

N.B. Two Dizygous pairs in Group IV not included since NO Monozygous pairs are in Group IV (deciduous)

Table XII

Mean Age and Mean Number of Permanent Teeth erupted

| | Fee-paying | | | Non-fee-paying | | |
|---|---|---|---|---|---|---|
| Group | No. of Children | Mean Age (yrs) | Mean No. of Teeth erupted | No. of Children | Mean Age (yrs) | Mean No. of Teeth erupted |
| **BOYS** | | | | | | |
| I | 6 | 6.27 | 2.17 | 12 | 6.22 | 2.33 |
| II | 6 | 6.57 | 6.50 | 12 | 6.58 | 6.25 |
| III | 28 | 8.89 | 11.00 | 56 | 8.89 | 11.34 |
| IV | 10 | 9.62 | 14.40 | 20 | 9.63 | 14.40 |
| V | 6 | 11.16 | 18.17 | 12 | 11.22 | 18.08 |
| VI | 17 | 12.63 | 22.88 | 34 | 12.64 | 22.91 |
| VII | 87 | 14.86 | 27.39 | 174 | 14.87 | 27.44 |
| VIII | 8 | 17.01 | 30.50 | 16 | 17.02 | 30.00 |
| **GIRLS** | | | | | | |
| I | 6 | 6.28 | 2.67 | 12 | 6.28 | 2.92 |
| II | 10 | 6.74 | 7.1 | 20 | 6.78 | 6.40 |
| III | 18 | 8.08 | 11.17 | 36 | 8.12 | 11.17 |
| IV | 13 | 9.44 | 14.31 | 26 | 9.45 | 14.35 |
| V | 9 | 10.92 | 18.22 | 18 | 10.92 | 19.00 |
| VI | 12 | 12.57 | 23.25 | 24 | 12.57 | 22.58 |
| VII | 97 | 14.83 | 27.44 | 194 | 14.84 | 27.44 |
| VIII | 4 | 17.07 | 30.50 | 8 | 16.59 | 30.50 |

Table XIII

Dental Caries in relation to Height

BOYS

| No. of Children | Tallest Third | | | | Shortest Third | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean Age yrs. | Mean No. Teeth erupted | Mean No. of D.M.F. Teeth per Child | D.M.F. per 100 Teeth erupted | Mean Age yrs. | Mean No. Teeth erupted | Mean No. of D.M.F. Teeth per Child | D.M.F. per 100 Teeth erupted |
| 23 | 12.6 | 25.7 | 3.5 | 13.7 | 12.5 | 23.8 | 3.4 | 14.2 |
| 24 | 13.5 | 26.5 | 3.8 | 14.3 | 13.2 | 25.2 | 3.5 | 13.9 |
| 24 | 14.5 | 27.6 | 5.9 | 21.3 | 14.5 | 26.4 | 3.9 | 14.7 |
| 21 | 15.4 | 27.8 | 5.6 | 20.2 | 15.2 | 27.2 | 5.4 | 19.7 |
| 13 | 16.6 | 28.5 | 10.1 | 35.3 | 16.4 | 27.7 | 6.1 | 22.2 |
| 10 | 17.5 | 28.6 | 8.1 | 28.3 | 17.4 | 28.7 | 6.5 | 22.6 |
| | | | | GIRLS | | | | |
| 26 | 12.7 | 26.2 | 5.2 | 19.8 | 12.5 | 25.1 | 3.2 | 12.9 |
| 26 | 13.6 | 26.8 | 5.0 | 18.7 | 13.4 | 26.2 | 4.4 | 16.7 |
| 17 | 14.6 | 27.6 | 6.8 | 24.5 | 14.4 | 26.8 | 4.8 | 17.8 |
| 19 | 15.5 | 28.1 | 8.6 | 30.7 | 15.3 | 27.7 | 7.3 | 26.2 |
| 14 | 16.5 | 28.9 | 8.4 | 29.0 | 16.4 | 28.1 | 6.4 | 22.9 |
| 19 | 17.5 | 28.0 | 8.4 | 30.2 | 17.5 | 27.8 | 9.5 | 34.4 |

Table XIV

Dental Caries in relation to Weight

| No. of Children | Heaviest Third | | | | Lightest Third | | | |
|---|---|---|---|---|---|---|---|---|
| | Mean Age yrs. | Mean No. Teeth erupted | Mean No. of D.M.F. Teeth per Child | D.M.F. per 100 Teeth erupted | Mean Age yrs. | Mean No. Teeth erupted | Mean No. of D.M.F. Teeth per Child | D.M.F. per 100 Teeth erupted |
| BOYS | | | | | | | | |
| 23 | 12.6 | 25.3 | 3.0 | 12.0 | 12.5 | 23.3 | 3.7 | 15.9 |
| 24 | 13.6 | 26.6 | 3.2 | 11.9 | 13.4 | 24.8 | 3.6 | 14.6 |
| 24 | 14.5 | 27.7 | 5.9 | 21.4 | 14.5 | 26.6 | 4.5 | 17.1 |
| 21 | 15.4 | 27.6 | 6.4 | 23.1 | 15.2 | 27.3 | 5.1 | 18.8 |
| 13 | 16.6 | 28.1 | 8.0 | 28.4 | 16.4 | 27.8 | 5.6 | 20.2 |
| 10 | 17.4 | 28.8 | 8.0 | 27.8 | 17.4 | 28.6 | 8.1 | 28.3 |
| GIRLS | | | | | | | | |
| 26 | 12.6 | 26.2 | 4.4 | 16.9 | 12.5 | 25.2 | 4.2 | 16.8 |
| 26 | 13.6 | 27.1 | 5.6 | 20.8 | 13.3 | 26.1 | 4.3 | 16.6 |
| 17 | 14.5 | 27.3 | 6.6 | 24.3 | 14.4 | 26.8 | 5.5 | 20.6 |
| 19 | 15.5 | 28.1 | 7.2 | 25.5 | 15.3 | 27.6 | 6.5 | 23.7 |
| 14 | 16.6 | 28.6 | 9.5 | 33.2 | 16.4 | 28.2 | 6.9 | 24.3 |
| 9 | 17.6 | 28.3 | 9.1 | 32.2 | 17.4 | 27.8 | 7.2 | 26.0 |

## Table XV

The number and percentage of Boys in the various stages of sexual maturation

BOYS

| Age Group | Number | | | | | | Percentage | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tallest | | | Shortest | | | Tallest | | | Shortest | | |
| | NP | PB | AD | NP | PB | AD | NP | PB | AD | NP | PB | AD |
| 12 | 11 | 12 | - | 22 | 1 | - | 48 | 52 | - | 96 | 4 | - |
| 13 | 4 | 19 | 1 | 21 | 3 | - | 17 | 79 | 4 | 87 | 13 | - |
| 14 | - | 18 | 6 | 13 | 10 | 1 | - | 75 | 25 | 54 | 42 | 4 |
| 15 | - | 2 | 19 | 2 | 16 | 3 | - | 9 | 91 | 9 | 77 | 14 |
| 16 | - | - | 13 | - | 8 | 5 | - | - | 100 | - | 62 | 38 |
| 17 | - | - | 10 | - | 1 | 9 | - | - | 100 | - | 10 | 90 |
| Total | 15 | 51 | 49 | 58 | 39 | 18 | 13 | 44 | 43 | 50 | 34 | 16 |

| Age Group | Number | | | | | | Percentage | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Heaviest | | | Lightest | | | Heaviest | | | Lightest | | |
| | NP | PB | AD | NP | PB | AD | NP | PB | AD | NP | PB | AD |
| 12 | 10 | 13 | - | 23 | - | - | 43 | 57 | - | 100 | - | - |
| 13 | 4 | 19 | 1 | 22 | 2 | - | 17 | 79 | 4 | 92 | 8 | - |
| 14 | - | 17 | 7 | 16 | 8 | - | - | 71 | 29 | 67 | 33 | - |
| 15 | - | 4 | 17 | 3 | 16 | 2 | - | 19 | 81 | 14 | 77 | 9 |
| 16 | - | - | 13 | - | 8 | 5 | - | - | 100 | - | 62 | 38 |
| 17 | - | - | 10 | - | 1 | 9 | - | - | 100 | - | 10 | 90 |
| Total | 14 | 53 | 48 | 64 | 35 | 16 | 12 | 46 | 42 | 56 | 30 | 14 |

NP = Non-pubescent

PB = Pubescent

AD = Adolescent

Table XVI

The number and percentage of Girls in the various stages of sexual maturation

GIRLS

| Age Group | Number | | | | | | Percentage | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Tallest | | | Shortest | | | Tallest | | | Shortest | | |
| | NP | PB | AD | NP | PB | AD | NP | PB | AD | NP | PB | AD |
| 12 | - | 21 | 5 | 9 | 17 | - | - | 81 | 19 | 35 | 65 | - |
| 13 | - | 9 | 17 | 3 | 16 | 7 | - | 35 | 65 | 12 | 61 | 27 |
| 14 | - | 3 | 14 | 1 | 4 | 12 | - | 18 | 82 | 6 | 24 | 70 |
| 15 | - | 1 | 18 | - | 1 | 18 | - | 5 | 95 | - | 5 | 95 |
| 16 | - | - | 14 | - | - | 14 | - | - | 100 | - | - | 100 |
| 17 | - | - | 9 | - | - | 9 | - | - | 100 | - | - | 100 |
| Total | - | 34 | 77 | 13 | 38 | 60 | - | 31 | 69 | 12 | 34 | 54 |

| Age Group | Number | | | | | | Percentage | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Heaviest | | | Lightest | | | Heaviest | | | Lightest | | |
| | NP | PB | AD | NP | PB | AD | NP | PB | AD | NP | PB | AD |
| 12 | - | 22 | 4 | 13 | 11 | 2 | - | 85 | 15 | 50 | 42 | 8 |
| 13 | - | 5 | 21 | 3 | 20 | 3 | - | 19 | 81 | 12 | 76 | 12 |
| 14 | - | 2 | 15 | 1 | 6 | 10 | - | 12 | 88 | 6 | 35 | 59 |
| 15 | - | - | 19 | - | 3 | 16 | - | - | 100 | - | 16 | 84 |
| 16 | - | - | 14 | - | - | 14 | - | - | 100 | - | - | 100 |
| 17 | - | - | 9 | - | - | 9 | - | - | 100 | - | - | 100 |
| Total | 29 | 29 | 82 | 17 | 40 | 54 | - | 26 | 74 | 15 | 36 | 49 |

NP = Non-pubescent

PB = Pubescent

AD = Adolescent

Table XVII

Mean number of teeth erupted per child and assessment of sexual maturation

| Age yrs. | Assessment of Sexual Maturity | Boys | | Girls | |
|---|---|---|---|---|---|
| | | No. of Children | Mean No. of Teeth erupted | No. of Children | Mean No. of Teeth erupted |
| 11 | Non-pubescent | - | - | 29 | 21.69 |
| | Pubescent | - | - | 34 | 24.09 |
| 12 | Non-pubescent | 70 | 24.14 | 13 | 25.69 |
| | Pubescent | 21 | 25.90 | 67 | 25.60 |
| | Adolescent | - | - | 7 | 26.71 |
| 13 | Non-pubescent | 42 | 25.55 | - | - |
| | Pubescent | 43 | 25.98 | 39 | 26.79 |
| | Adolescent | - | - | 46 | 27.04 |
| 14 | Non-pubescent | 19 | 26.58 | - | - |
| | Pubescent | 53 | 27.28 | 13 | 26.54 |
| | Adolescent | 15 | 27.47 | 54 | 27.46 |
| 15 | Pubescent | 35 | 27.34 | - | - |
| | Adolescent | 52 | 27.69 | - | - |

Eruption of the Permanent Teeth

A tooth was recorded as erupting when the tip of the cusp was observed to be penetrating the overlying mucosa up to approximately 2 mm. No tooth further advanced in eruption was recorded other than as "present".

The measure of 2 millimetres was arbitrarily chosen, but it was considered a reasonable limit to emergence of a tooth and stricter limits seemed impracticable.

For each morphological class of tooth the mean age at which is was observed to be erupting was computed.

The differences between corresponding teeth on opposite sides was not found to be statistically significant. For convenience, the data are presented with values derived from right and left sides combined as a composite for each jaw.

In Table XVIII following, the mean ages of emergence of the various classes of permanent teeth are shown. (The third molar provided such scanty data that it has been omitted.)

Table XVIII

Mean age of eruption of the Permanent Teeth

| | Boys | | | Girls | | |
|---|---|---|---|---|---|---|
| Tooth | Mean Age (years) | Limits ± 2 S.E. Upper | Lower | Mean Age (years) | Limits ± 2 S.E. Upper | Lower |
| **Maxilla** | | | | | | |
| $I_1$ | 7.73 | 7.81 | 7.65 | 7.69 | 7.77 | 7.61 |
| $I_2$ | 8.64 | 8.76 | 8.52 | 8.38 | 8.48 | 8.28 |
| C | 11.78 | 11.90 | 11.66 | 11.26 | 11.38 | 11.14 |
| $PM_1$ | 10.69 | 10.81 | 10.57 | 10.43 | 10.55 | 10.31 |
| $PM_2$ | 11.07 | 11.23 | 10.91 | 10.85 | 10.99 | 10.71 |
| $M_1$ | 6.37 | 6.51 | 6.23 | 6.30 | 6.42 | 6.18 |
| $M_2$ | 12.32 | 12.50 | 12.14 | 12.09 | 12.25 | 11.93 |
| **Mandible** | | | | | | |
| $I_1$ | 7.01 | 7.07 | 6.95 | 6.87 | 6.95 | 6.79 |
| $I_2$ | 7.76 | 7.86 | 7.66 | 7.60 | 7.70 | 7.50 |
| C | 11.15 | 11.27 | 11.03 | 10.16 | 10.26 | 10.06 |
| $PM_1$ | 11.09 | 11.21 | 10.97 | 10.82 | 10.94 | 10.70 |
| $PM_2$ | 11.66 | 11.86 | 11.44 | 11.39 | 11.59 | 11.19 |
| $M_1$ | 6.41 | 6.53 | 6.29 | 6.32 | 6.46 | 6.18 |
| $M_2$ | 12.27 | 12.41 | 12.13 | 11.91 | 12.05 | 11.77 |

$I_1$ - Central incisor

$I_2$ - Lateral incisor

C - Canine

$PM_1$ - First Premolar

$PM_2$ - Second Premolar

$M_1$ - First Molar

$M_2$ - Second Molar

The mean age of eruption of permanent teeth in the Edinburgh sample is presented in Table XIX, together with the values derived from four previous surveys in England and Wales for comparison.

Table XIX

Mean age of eruption of permanent teeth
British Children

| Tooth | James & Pitts 1911-12 | Ainsworth 1925 | | Stones et al. 1951 | | Clements et al. 1953 | | Edinburgh Children 1955 | |
|---|---|---|---|---|---|---|---|---|---|
| | M + F | M | F | M | F | M | F | M | F |
| **Maxilla** | | | | | | | | | |
| $I_1$ | 7.5 | 7.42 | 7.26 | 8.10 | 7.67 | 7.01 | 6.62 | 7.73 | 7.69 |
| $I_2$ | 8.75 | 8.81 | 8.37 | 8.85 | 8.66 | 8.18 | 7.82 | 8.64 | 8.38 |
| C | 11.75 | 11.73 | 11.20 | 12.24 | 12.01 | 11.46 | 10.67 | 11.78 | 11.26 |
| $PM_1$ | 10.0 | 9.96 | 9.77 | 10.93 | 10.47 | 10.41 | 9.79 | 10.69 | 10.43 |
| $PM_2$ | 11.0 | 10.89 | 10.72 | 11.38 | 11.11 | 11.51 | 11.06 | 11.07 | 10.85 |
| $M_1$ | 6.25 | 6.34 | 6.12 | 6.72 | 6.60 | 6.12 | 5.94 | 6.37 | 6.30 |
| $M_2$ | 12.0+ | 12.33 | 12.07 | 12.43 | 12.11 | 11.97 | 11.50 | 12.32 | 12.09 |
| **Mandible** | | | | | | | | | |
| $I_1$ | 6.5 | 6.49 | 6.23 | 6.85 | 6.81 | 6.08 | 5.77 | 7.01 | 6.87 |
| $I_2$ | 7.5 | 7.72 | 7.50 | 8.12 | 8.05 | 7.30 | 7.01 | 7.76 | 7.60 |
| C | 10.5 | 10.80 | 9.90 | 11.41 | 10.67 | 10.51 | 9.41 | 11.15 | 10.16 |
| $PM_1$ | 10.5 | 10.86 | 10.36 | 11.40 | 11.43 | 11.35 | 10.53 | 11.09 | 10.82 |
| $PM_2$ | 12.00 | 11.80 | 11.21 | 12.12 | 12.01 | 12.32 | 11.63 | 11.66 | 11.39 |
| $M_1$ | 6.0 | 6.24 | 5.95 | 6.91 | 6.57 | 6.14 | 5.84 | 6.41 | 6.32 |
| $M_2$ | 12.0 | 11.86 | 11.52 | 12.16 | 12.21 | 11.41 | 11.18 | 12.27 | 11.91 |

Sequence of Eruption

The sequence of eruption of the permanent teeth in Edinburgh children is shown in Table XX, together with the reported sequences for the other studies of British children in the past.

The sequence for Edinburgh children can be seen to agree with those derived from earlier surveys.

Table XX

Sequence of eruption of the permanent teeth

| Tooth | James & Pitts 1911-12 | Ainsworth 1925 | | Stones et al. 1951 | | Clements et al. 1953 | | Edinburgh Children 1951-53 | |
|---|---|---|---|---|---|---|---|---|---|
| | M + F | M | F | M | F | M | F | M | F |
| **Maxilla** | | | | | | | | | |
| $I_1$ | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| $I_2$ | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| C | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 6 | 6 |
| $PM_1$ | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| $PM_2$ | 5 | 5 | 5 | 5 | 5 | 6 | 6 | 5 | 5 |
| $M_1$ | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| $M_2$ | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 |
| **Mandible** | | | | | | | | | |
| $I_1$ | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 2 | 2 |
| $I_2$ | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| C | 5 | 4 | 4 | 5 | 4 | 4 | 4 | 5 | 4 |
| $PM_1$ | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 4 | 5 |
| $PM_2$ | 6 | 6 | 6 | 6 | 6 | 7 | 7 | 6 | 6 |
| $M_1$ | 1 | 1 | 1 | 2 | 1 | 2 | 2 | 1 | 1 |
| $M_2$ | 7 | 7 | 7 | 7 | 7 | 6 | 6 | 7 | 7 |